TRANSACTIONS

OF

THE ACADEMY OF SCIENCE
OF ST. LOUIS.

VOL. IX.

JANUARY 1899 TO DECEMBER 1899.

PUBLISHED UNDER DIRECTION OF THE COUNCIL.

ST. LOUIS:
NIXON-JONES PRINTING CO.

CONTENTS.

CORRECTIONS.

P. 43, line 6 from top. — Insert definitely after been.
Pp. 47–9. — For Tribloceras read Triboloceras.
P. 51. — For Triblocerus read Triboloceras.
P. 66, line 21 from bottom. — For ten read twenty.

MEMBERS.

1. PATRONS.

Harrison, Edwin	3747 Westminster pl.

2. ACTIVE MEMBERS.

Adkins, James	3901 Park av.
Alleman, Gellert	Washington University.
Alt, Adolf	3036 Locust st.
Bain, Robert E. M	901 Olive st.
Baker, Carl F	3504a Bell av.
Ball, David C	310 Merchants' Exch.
Barck, C	2715 Locust st.
Bartlett, George M	215 Pine st.
Baumgarten, Gustav	2643 Chestnut st.
Becktold, William B	212 Pine st.
Bernays, A. C	3623 Laclede av.
Biebinger, Frederick W	1421 S. 11th st.
Bixby, William K	13 Portland pl.
Bliss, Malcolm A	4929 Lotus av.
Boogher, John H	4034 Delmar boul.
Bouton, Charles L	Harvard University, Cambridge, Mass.
Branch, Henry	4314 Washington av.
Bremer, Ludwig	3723 West Pine boul.
Brennan, Martin S	1414 O'Fallon st.
Brookings, Robert S	5125 Lindell av.
Brown, Daniel S	2212 DeKalb st.
Bryson, John P	209 N. Garrison av.
Budgett, Sidney Payne	1806 Locust st.
Burg, William	1756 Missouri av.
Burnett, E. C	University Club.
Busch, Adolphus	Busch pl.
Busch, Aug. A.	Busch pl.
Bush, B. F	Courtney, Mo.
Carpenter, George O	Russell and Compton avs.
Carter, Howard	Old Orchard, Mo.

Carver, George W.....................Tuskegee, Alabama.
Chaplin, Winfield S.....................3636 West Pine boul.
Chase, E. C.. ....3325 Morgan st.
Chauvenet, Louis.......................5501 Chamberlain av.
Chouteau, Charles P.....................918 Security bldg.
Clifford, Alfred.........................4168 West Pine boul.
Compton, P. C..........................4156 Washington boul.
Comstock, T. Griswold...............3401 Washington av.
Coulter, John M........................University of Chicago,
Chicago, Ill.
Crandall, George C....................620 N. Garrison av.
Crunden, Frederick M.............. Public Library.
Curtis, William S.......................St. Louis Law School.
Cushman, Allerton S..................Harvard University,
Cambridge, Mass.

Dameron, E. C...........................Clarksville, Mo.
Davis, H. N................ ....56 Vandeventer pl.
Davis, John D.................... ......421 Olive st.
Diehm, Ferdinand......................Fourth Nat. Bank.
Dodd, S. M...............................415 Locust st.
Douglas, Archer W.......... ....9th and Spruce sts.
Drake, George S........................64 Vandeventer pl.
Duenckel, F. W.........................3634 Russell av.
Durant, George F......................9 Benton pl.

Eberlein, W. P..........................3655 Cleveland av.
Eggert, Henry.............................1001 Collinsville av.,
East St. Louis, Ill.
Eliot, Edward C........................5468 Maple av.
Eliot, Henry W ....2635 Locust st.
Engler, Edmund Arthur.............Washington University.
Erker, Adolph P ....608 Olive st.
Espenschied, Charles..................3500 Washington av.
Euston, Alexander......................3730 Lindell boul.
Evers, Edward...........................1861 N. Market st.
Ewing, Arthur E........................3333 Washington av.

Fischel, Washington E...............2647 Washington av.
Flersheim, George W.................4429 Delmar av.
Forbes, S. A.............................Urbana, Ill.
Fordyce, John R........................3634 Washington boul.
Francis, David R.......................4421 Maryland av.

Frankenfield, H. C.	U. S. Weather Bureau, Washington, D. C.
Frerichs, Frederick W	Care of Herf & Frerichs Chem. Co.
Fruth, Otto J	3066 Hawthorne boul.
Fry, Frank R	3133 Pine st.
Funkhouser, Robert M	3534 Olive st.
Gazzam, J. B	514 Security bldg.
Glasgow, Frank A	3894 Washington boul.
Glasgow, William C	2847 Washington av.
Goldstein, Max A	3702 Olive st.
Goodman, Charles H	3329 Washington av.
Gottschalk, Fred. F	619 Pine st.
Graham, B. B	3500 Morgan st.
Graves, William W	1943 N. 11th st.
Gray, Melvin L	3756 Lindell boul.
Green, John	2670 Washington av.
Gregory, Elisha H., Jr	Harvard Med. School, Boston.
Grindon, Joseph	509 N. Theresa av.
Grocott, Willis H	1812 Coleman st.
Gurney, James	Tower Grove and Magnolia avs.
Haarstick, Henry C	Main and Walnut sts.
Hambach, G	Washington University.
Hammon, W. H	U. S. Weather Bureau, San Francisco, Cal.
Hardaway, W. A.	2922 Locust st.
Hartmann, Rudolph	14 S. 2d st.
Herthel, Adolph	1739 Waverly pl.
Herzog, William	2321 Whittemore pl.
Hirschberg, Francis D	3818 Lindell boul.
Hitchcock, Albert Spear	Manhattan, Kas.
Hitchcock, Henry	709 Wainwright bldg.
Hodgman, Charles	300 N. 4th st.
Holman, M. L	3744 Finney av.
Holmes, John M	3810 Page av.
Hough, Warwick	3877 Washington boul.
Hughes, Charles Hamilton	3860 West Pine boul.
Hugunin, F. U	915 Olive st.
Huiskamp, John E	5554 Cabanne av.
Hume, H. Harold	Lake City, Florida.
Hunicke, Henry August	3532 Victor st.
Hurter, Julius	2346 S. 10th st.

Ives, Halsey C.........................Museum of Fine Arts.

James, John A. James ....2836 Lafayette av.
Jester, E. T.............................2342 Whittemore pl.
Johnson, Dr. J. B.....................4244 Washington boul.
Johnson, Professor J. B.............Madison, Wis.
Johnson, Reno DeO ....Desloge, Mo.
Jones, Breckinridge...................4010 Lindell boul.
Judson, Frederick N..................500 Rialto bldg.

Keiser, Edward H ....Washington University.
Kennett, A. Q............................2916 Lucas av.
Keyes, Charles R.......................944 Fifth st., Des Moines, Ia.
Kinealy, John H........................Washington University.
King, Goodman ....78 Vandeventer pl.
Kinsley, Carl.............................Governor's Island, N. Y. City.
Kinsman, George C...................Decatur, Ill.
Kline, George R........................215 Pine st.
Kodis, Theo ....3218 Pine st.
Krall, George W........................Manual Training School.
Kromrey, Hugo..........................513 Walnut st.

Lackland, Rufus J....................1623 Locust st.
Langsdorf, Alexander S. ....Washington University.
Lazell, Ellis W..........................Spencer, Mass.
Leighton, George B....................803 Garrison av.
Leighton, George E....................803 Garrison av.
Lemoine, E. S............................3526 Washington av.
Letterman, George W.................Allenton, Mo.
Lichter, John J., Jr....................5305 Virginia av.
Loeb, Hanau Wolf......................3559 Olive st.
Lumelius, J. George...................1225 St. Ange av.

Mack, Charles J.........................113 N. Broadway.
Madill, George A........................4140 Lindell boul.
Mallinckrodt, Edward.................26 Vandeventer pl.
Markham, George D...................Colonial bldg.
Matthews, Leonard.....................300 N. 4th st.
McElwee, L. C...........................1113 N. Grand av.
McMillan, Wm...........................25 Portland pl.
Meier, Friederich ....German Consulate, Rotterdam, Holland.
Meier, Theodore G.....................3938 Washington boul.
Merrell, Albert...........................3814 Washington boul.

Michel, Eugene H......................2721 S. King's Highway.
Miller, Charles F.......................1751 Missouri av.
Moore, Robert..........................61 Vandeventer pl.
Morton, I. W............................9th and Spruce sts.
Mudd, Harvey G........................2604 Locust st.
Muegge, Aug. H........................2712 Franklin av.

Nagel, Charles..........................3969 Washington boul.
Nelson, N. O ....8th and St. Charles sts.
Nipher, Francis E......................Washington University.
Norton, J. B. S ....4159 McRee av.

Olshausen, Ernest P..................1115 Rutger st.
Olshausen, George R.................19 Artillerie st., Berlin, Germany.
O'Reilly, Andrew J....................326 City Hall.
O'Reilly, Robert J.....................3411 Pine st.
Overstolz, Herman.....................100 N. Broadway.

Pammel, Louis Hermann............Ames, Ia.
Parsons, Charles ....2804 Pine st.
Pegram, George H.....................195 Broadway, New York City.
Pettus, W. H. H ....2834 Chestnut st.
Pickard, John............................Columbia, Mo.
Pike, S. B.................................5555 Clemens av.
Pitzman, Julius.........................1900 S. Compton av.
Post, Martin Hayward...............3015 Lucas av.
Preetorius, Emil ....Care of Westliche Post.
Prewitt, Theodore F..................4615 Westminster pl.
Primm, Alexander T..................Care of J. Kennard & Sons.
Pritchett, Henry S.....................Care of U. S. Coast Survey,
Washington, D. C.
Pulsifer, William H...................Newton Centre, Mass.

Quaintance, A. L.......................Experiment, Ga.

Randall, J. E ....1910 Olive st.
Ravold, Amand ....2806 Morgan st.
Robert, E. S.............................Union Trust bldg.
Robertson, Charles....................Carlinville, Ill.
Roever, William Henry..............3628 St. Louis av.
Rolfs, P. H...............................Clemson College, S. C.
Runge, Edward C ....Supt. Insane Asylum.
Russell, Colton..........................4652 Wagoner pl.

Sander, Enno..........129 S. 11th st.
Sargent, Charles Sprague..........Jamaica Plain, Mass.
Schmalz, Leopold..........2824 Shenandoah av.
Schneck, Jacob..........Mt. Carmel, Ill.
von Schrenk, Hermann..........Washington University.
Schroers, John..........1730 Missouri av.
Schwarz, Henry..........1723 Chouteau av.
Schweitzer, Paul..........Columbia, Mo.
Scott, Henry C..........64 Vandeventer pl.
Seddon, James A..........1637 Indiana av., Chicago, Ill.
See, T. J. J..........Naval Observatory,
Washington, D. C.
Seever, William J..........1600 Locust st.
Selby, Augustine Dawson..........Wooster, Ohio.
Senseney, E. M..........2829 Washington av.
Sheldon, W. L..........4065 Delmar av.
Shepley, John F..........60 Vandeventer pl.
Simmons, E. C..........9th and Spruce sts.
Simmons, W. D..........Care of Simmons Hardware Co.
Sluder, Greenfield..........2647 Washington av.
Smith, D. S. H..........3646 Washington boul.
Smith, Holmes..........Washington University.
Smith, Irwin Z..........87 Vandeventer pl.
Smith, Jared G..........Dept. Agriculture,
Washington, D. C.
Spiegelhalter, Joseph..........2166 Lafayette av.
Starr, John E..........525 West st., N. Y. City.
Staudinger, B..........1703 Olive st.
Stedman, J. M..........Columbia, Mo.
Stevens, Charles D..........1749 S. Grand av.
Stone, Charles H..........City Hall.
Strauss, Julius C..........3516 Franklin av.
Sutter, Otto..........3035 Bell av.

Taussig, Albert E..........2318 Lafayette av.
Taussig, William..........3447 Lafayette av.
Teichmann, William C..........1141 Market st.
Terry, Albert Todd..........621 Chestnut st.
Terry, Robert J..........Mo. Medical College.
Thacher, Arthur..........4304 Washington boul.
Thiele, Albert..........2746 Park av.
Thurman, John S..........416 Lincoln Trust bldg.
Thomas, John R..........420 N. 4th st.

Timmerman, Arthur H.	2633 Park av.
Tittmann, Harold H	3726 Washington boul.
Trelease, William	Mo. Botanical Garden.
Tyrrell, Warren A.	3620a Folsom av.
Updegraff, Milton	Naval Observatory, Washington, D. C.
Vallé, Jules F	3303 Washington av.
Van Ornum, John Lane.	Washington University.
Vickroy, W. R	3029 Washington av.
Von Schrader, George F.	Wainwright bldg.
Von Schrader, Otto U.	3749 Westminster pl.
Wall, L. J. W.	21st and Morgan sts.
Walsh, Edward, Jr	Main and Angelica sts.
Watts, M. F.	4362 Morgan st.
Weller, Stuart.	University of Chicago, Chicago, Ill.
Wheeler, H. A.	3124 Locust st.
Whelpley, Henry Milton.	2342 Albion pl.
Whitaker, Edwards.	300 N. 4th st.
Whitten, John C.	Columbia, Mo.
Whittier, Charles Thurston.	Care of Provident Chemical Works.
Winkelmeyer, Christopher.	3540 Chestnut st.
Winslow, Arthur.	104 W. 9th st., Kansas City, Mo.
Wislizenus, Fred	3628 Cleveland av.
Witt, Thomas D.	6th and Olive sts.
Wood, O. M.	3016 Caroline st.
Woodward, C. M.	3013 Hawthorne boul.

THE ACADEMY OF SCIENCE OF ST. LOUIS.

ORGANIZATION.

The Academy of Science of St. Louis was organized on the 10th of March, 1856, in the hall of the Board of Public Schools. Dr. George Engelmann was the first president.

CHARTER.

On the 17th of January following, a charter incorporating the Academy was signed and approved, and this was accepted by vote of the Academy on the 9th of February, 1857.

OBJECTS.

The act of incorporation declares the object of the Academy to be the advancement of science and the establishment in St. Louis of a museum and library for the illustration and study of its various branches, and provides that the members shall acquire no individual property in the real estate, cabinets, library, or other of its effects, their interest being usufructuary merely.

The Constitution, as adopted at the organization meeting and amended at various times subsequently, provides for holding meetings for the consideration and discussion of scientific subjects; taking measures to procure original papers upon such subjects; the publication of transactions; the establishment and maintenance of a cabinet of objects illustrative of the several departments of science, and a library of works relating to the same; and the establishment of relations with other scientific institutions. To encourage and promote special investigation in any branch of science, the formation of special sections under the charter is provided for.

MEMBERSHIP.

Members are classified as active members, corresponding members, honorary members, and patrons. Active membership is limited to persons interested in science, though they need not of necessity be engaged in scientific work, and they alone conduct the affairs of the Academy, under its constitution. Persons not living in the city or county of St. Louis, who are disposed to further the objects of the Academy by original researches, contributions of specimens, or otherwise, are eligible as corresponding members. Persons not living in the city or county of St. Louis are eligible as honorary members by virtue of their attainments in science. Any person conveying to the Academy the sum of one thousand dollars or its equivalent becomes eligible as a patron.

Under the By-Laws, resident active members pay an initiation fee of five dollars and annual dues of six dollars. Non-resident active members pay the same initiation fee, but annual dues of three dollars only. Patrons, and honorary and corresponding members, are exempt from the payment of dues. Patrons and all active members not in arrears are entitled to one copy of each publication of the Academy issued after their election.

Since the organization of the Academy, 845 persons have been elected to membership, of whom, at the present time, 248 are carried on the active list. One person, Mr. Edwin Harrison, has been elected a patron. The present list of corresponding members includes 204 names.

OFFICERS AND MANAGEMENT.

The officers, who are chosen from the active members, consist of a President, two Vice-Presidents, Recording and Corresponding Secretaries, Treasurer, Librarian, three Curators, and two Directors. The general business management of the Academy is vested in a Council composed of the President, the two Vice-Presidents, the Recording Secretary, the Treasurer and the two Directors.

The office of President has been filled by the following well-known citizens of St. Louis, nearly all of whom have been eminent in some line of scientific work; George Engelmann, Benjamin F. Shumard, Adolphus Wislizenus, Hiram A. Prout, Dr. John B. Johnson, James B. Eads, William T.

Harris, Charles V. Riley, Francis E. Nipher, Henry S. Pritchett, John Green, Melvin L. Gray, and Edmund A. Engler.

MEETINGS.

The regular meetings of the Academy are held at its rooms, 1600 Locust Street, at 8 o'clock, on the first and third Monday evenings of each month, a recess being taken from the second June meeting to the first October meeting, inclusive. These meetings, to which interested persons are always welcome, are devoted in part to the reading of technical papers designed for publication in the Academy's Transactions, and in part to the presentation of more popular abstracts of recent investigation or progress. From time to time, public lectures calculated to interest a larger audience are provided for in some suitable hall.

LIBRARY.

After its organization, the Academy met in Pope's Medical College, where a creditable beginning had been made toward the formation of a museum and library, until May, 1869, when the building and museum were destroyed by fire, the library being saved. The library now contains some 13,215 books and 9,430 pamphlets, and is open during certain hours of the day for consultation by members and persons engaged in scientific work.

PUBLICATIONS AND EXCHANGES.

Nine octavo volumes of Transactions have been published since the organization of the Academy, and widely distributed. Two quarto publications have also been issued, one from the Archaeological Section, being a contribution to the archaeology of Missouri, and the other a report of the observations made by the Washington University Eclipse Party of 1889. The Academy now stands in exchange relations with 533 institutions or organizations of aims similar to its own.

MUSEUM.

Since the loss of its first museum, in 1869, the Academy has lacked adequate room for the arrangement of a public museum, and, although small museum accessions have been received and cared for, its main effort of necessity has been concentrated on the holding of meetings, the formation of a library, the publication of worthy scientific matter, and the maintenance of relations with other scientific bodies, through its active membership, which includes many business and professional men who are interested in the work and objects of the Academy, although not themselves investigators.

December 30, 1899.

RECORD.

From January 1, 1899, to December 31, 1899.

January 9, 1899.

President Engler in the chair, fifteen persons present.

The nominating committee reported that 117 ballots had been counted, and the following officers for 1899 were declared duly elected: —

President	Edmund A. Engler.
First Vice-President	Robert Moore.
Second Vice-President	D. S. H. Smith.
Recording Secretary	William Trelease.
Corresponding Secretary	Joseph Grindon.
Treasurer	Enno Sander.
Librarian	Gustav Hambach.
Curators	Gustav Hambach, Julius Hurter, Hermann von Schrenk.
Directors	M. H. Post, Amand Ravold.

The President delivered an address on the condition and work of the Academy.*

The Treasurer submitted his annual report, showing invested funds to the amount of $6,400.00, and a current balance of $704.88, carried forward to the year 1899.†

The Librarian submitted his annual Report.‡

Mr. H. von Schrenk presented informally the results of a study of a sclerotium disease of beech roots which he had observed in southeastern New York during the past summer. The sclerotia, which were formed by the webbing together of rootlets by sterile mycelial threads, were stated by the

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* Transactions 8: xxvi. † Transactions 8: xxix. ‡ Transactions 8: xxx.

speaker to have apparently no connection with the mycorrhiza of the beech. Mr. von Schrenk's remarks were illustrated by drawings and alcoholic and sectioned specimens.

One person was proposed for active membership.

JANUARY 23, 1899.

President Engler in the chair, fifteen persons present.

The resignation of Dr. H. N. Spencer, Mr. A. J. Vanlandingham and Mr. James E. Yeatman, the cancellation of the names of Drs. J. A. Close and J. E. Neville, and the addition of the Literary and Scientific Society of Ottawa, the Pasadena Academy of Sciences, and the University of Tennessee to the exchange list of the Academy, were reported by the Council.

A paper by Professor A. S. Hitchcock, entitled Studies on subterranean organs. I. Compositae of the vicinity of Manhattan, Kansas, was presented in abstract.

Mr. C. H. Thompson spoke of some plants the flowers of which originate endogenously. He mentioned several species of *Rhipsalis* in which the much reduced leaves grow on triangular or cylindrical very succulent stems, their axillary buds originating deep down in the soft tissue and sometimes having a passageway extending toward the surface. In two species of *Rhipsalis* (*R. paradoxa* and *R. floccosa*) there is no such passageway, and the bud, in developing, breaks through the epidermis. In *Rhipsalis glaucosa*, a number of accessory abortive flowers were found. *Cuscuta glomerata* was mentioned as the only other plant in which, so far as the speaker knew, subepidermal flowers occur.

Mr. Aug. A. Busch, of St. Louis, was elected to active membership.

Two persons were proposed for active membership.

FEBRUARY 6, 1899.

President Engler in the chair, thirty-four persons present.

Professor F. E. Nipher presented, in an informal manner, some recent conceptions in physical science.

Mr. Albert Todd Terry and Mr. John Hopkins Terry, of St. Louis, were elected to active membership.

Two persons were proposed for active membership.

February 20, 1899.

President Engler in the chair, seventeen persons present.

Mr. H. A. Hunicke delivered an informal lecture on the new elements recently discovered in the atmosphere, giving an account of the discovery of argon, helium, crypton, neon, metargon, and xenon, and indicating the places in the periodic system, as suggested by Ramsey, for all except crypton and metargon, which as yet are too little known to make this possible.

One person was proposed for active membership.

March 6, 1899.

President Engler in the chair, nineteen persons present.

Professor J. H. Kinealy described some experiments on lifting water by compressed air, as is done by the Pohle air-lift pump, and discussed the efficiency problems of the use of apparatus of this description.

Mr. E. H. Michel, Mr. J. E. Randall, and Mr. John S. Thurman, all of St. Louis, were elected to active membership.

Two persons were proposed for active membership.

March 20, 1899.

President Engler in the chair, fifty-three persons present.

The Council reported that the resignations of Dr. H. Kinner and Professor C. R. Sanger had been accepted; that at his request the name of Judge Franklin Ferriss had been dropped from the roll of members, he having never qualified as a member; and that the Academy had lost a member by the death of Mr. W. S. Burroughs.

Dr. T. J. J. See addressed the Academy on the temperature and relative ages of the stars and nebulae, rejecting the commonly accepted view that the elements of the solar systems have always been heated to an intense point and are in process of cooling, and presenting a mathematical discussion of the theory that the solar bodies have at first been aggregates of cooled, slightly phosphorescent matter which has become heated through the shrinkage of the mass, under the influence of gravitation, up to a critical point, beyond which cooling must result.

Professor C. M. Woodward presented informally the results of a mathematical analysis of the phenomena in a theoretical gaseous sphere.

A paper by Professor Pammel, entitled Anatomical characters of the seeds of Leguminosae, chiefly genera of Gray's Manual, was presented by title.

Dr. C. H. Hughes and Mr. J. E. Huiskamp were elected to active membership.

APRIL 3, 1899.

President Engler in the chair, seven members and two visitors present.

A paper by Mr. Stuart Weller, entitled Kinderhook faunal studies. I. The fauna of the Vermicular Sandstone at Northview, Webster County, Missouri, was presented in abstract.

Mr. Trelease exhibited a plaster cast of a gigantic cactus monstrosity from Mexico, known as the Rosa de Organo, and presented to the Missouri Botanical Garden by Professor Frederick Starr, who reported that this was here and there an abundant growth on the common organ cactus from Aguas Calientes southward. The speaker exhibited a large number of comparable cactus monstrosities from the living collections of the Missouri Botanical Garden and the collection of Dr. A. A. Kleinschmidt, President of the Cactus Association of St. Louis, and a similar deformity of one of the cactus-like Euphorbias of the African region, calling attention to the fact that these unusual growths, which are occasional in most of the genera of Cactaceae, are of the same general character as the fasciations and similar deformities of plants belonging to other groups. It was shown that for the purposes of gardeners, for whom these unusual forms appear to possess a considerable interest, they are commonly divided into two types, in one of which, usually designated by the varietal name cristata or cristatus, the monstrosity takes the form either of a fan or a contorted ridge, while in the other, commonly designated by the varietal name monstrosus, it consists in an irregular bunching of the branches, accompanied by an interruption of the customary longitudinal ridges in such a genus as *Cereus*.

APRIL 17, 1899.

President Engler in the chair, nine persons present.

A paper by Mr. C. R. Ball, entitled Notes on some western willows, was presented by J. B. S. Norton.

Professor F. E. Nipher gave a brief exhibition of the action of the Wehnelt current interrupter, mentioning the uses to which it may be put, and in particular its application to wireless telegraphy and X-ray work, where it eliminates the necessity for a condenser in connection with the induction coil.

MAY 1, 1899.

President Engler in the chair, twenty persons present.

The Council reported that in conformity with Article XIII. of the By-laws the following names had been canceled from the list of members: Charles Bailey, Robert Collins, Eliot C. Jewett, F. Kolbenheyer, B. D. Kribben, W. B. Potter, A. Ramel, Paul Wittenberg; and that the Academy had lost two members by the recent death of Mr. George W. Parker and General John W. Turner.

A paper by Professor F. E. Nipher, On gravitation in gaseous nebulae, was presented by title.

Dr. Amand Ravold exhibited cultures and microscopic specimens showing the *Micrococcus intercellularis meningitidis* of Weichselbaum, obtained from a case of cerebro-spinal meningitis, and stated that this case afforded an interesting instance of germ infection through the placenta, inasmuch as the cerebro-spinal system of an unborn child of the patient was likewise found to be infected by the germ, — from which, in fact, the specimens exhibited were derived.

Mr. H. von Schrenk presented the general results of a study of certain diseases of the yellow pine, illustrating his remarks by the exhibition of a large number of specimens showing the characteristic phenomena of the diseases, and the fruiting bodies of the fungi which cause them.

MAY 15, 1899.

President Engler in the chair, thirty-one persons present.

A paper by Professor F. E. Nipher on temperatures of gaseous nebulae, was presented by title.

Professor Edward M. Shepard exhibited an interesting series of lantern slides and specimens procured by him during a recent extended trip through the islands of the South Pacific, especially New Zealand, Fiji and Samoa, illustrating the natural history and ethnology of those islands.

Two persons were proposed for active membership.

JUNE 5, 1899.

President Engler in the chair, twenty-two persons present

Dr. Enno Sander presented to the library of the Academy a volume entitled Bibliographie de l'Anarchie, by M. Nettlau.

A paper by Mr. Charles Thom, entitled The process of fertilization in Aspidium and Adiantum, was presented by title.

Mr. J. B. S. Norton spoke of some trees of *Crataegus* found near East St. Louis, Illinois, which are supposed to be hybrids of *Crataegus Crus-galli* and *C. viridis.* The trees have many characters common to both species. They occur intimately associated with the supposed parents, and have a comparatively local range. As opposed to the view that they are hybrids are the constancy of the characters, relative abundance of seed, and the presence of a large number of individuals.

Mr. H. von Schrenk gave a brief description of some peculiar wounds found on two-year-old twigs of nearly all woody plants growing in St. Louis and vicinity.

Professor F. E. Nipher gave an informal talk on the methods of making liquid air, describing the process by which Mr. Tripler makes liquid air in large quantities.

Dr. Max A. Goldstein and Mr. John Schroers, of St. Louis, were elected to active membership.

OCTOBER 16, 1899.

President Engler in the chair, thirteen persons present.

A paper by Dr. T. J. J. See, On the temperature of the sun and on the relative ages of the stars and nebulae, was presented in abstract by Professor F. E. Nipher.

Dr. H. von Schrenk presented some notes on *Arceuthobium pusillum*, which was found in Maine during the past summer, growing on the white spruce along the sea-coast. The trees which are attacked form large witches' brooms, the branches of which are much longer than the normal branches. The manner in which the seeds are disseminated was briefly described, and seeds were exhibited adhering to branches of the white spruce.

Ten persons were proposed for active membership.

NOVEMBER 6, 1899.

President Engler in the chair, eleven persons present.

The Council reported the resignation of J. H. Terry and E. C. Tittmann.

The presentation to the Academy library, by Dr. Enno Sander, of a set of the Messages and Papers of the Presidents of the United States, in ten volumes, was announced.

Professor J. H. Kinealy presented informally the results of an investigation into the distributions of light from certain fixed centers, when used for the illumination of a room.

A paper by Mr. Stuart Weller, entitled Kinderhook faunal studies. II. The fauna of the Chonopectus Sandstone at Burlington, Iowa, was presented in abstract.

The following persons were elected active members: Gellert Alleman, C. F. Baker, Edward H. Keiser and Albert Thiele, of St. Louis; B. F. Bush, of Courtney, Missouri; George W. Carver, of Tuskegee, Alabama; H. H. Hume, of Lake City, Florida; Charles Sprague Sargent, of Brookline, Massachusetts; Augustine D. Selby, of Wooster, Ohio; and Stuart Weller, of Chicago.

One person was proposed for active membership.

NOVEMBER 20, 1899.

President Engler in the chair, twenty-five persons present.

The death of Dr. H. H. Mudd, a member of the Academy, was announced by the Council.

Dr. G. Hambach exhibited two specimens of coral presented to the museum by Mr. Julius Hurter.

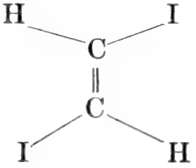
Professor F. E. Nipher addressed the Academy informally on Conditions existing in solid, liquid and gaseous states of matter, in the light of recent developments.

Professor John Lane Van Ornum, of St. Louis, was elected to active membership.

DECEMBER 4, 1899.

President Engler in the chair, fifteen persons present.

Dr. Edward H. Keiser talked informally on Some derivatives of acetylene, exhibiting specimens of the new liquid acetylene iodide discovered by him in January, 1899. He described the methods of making the compound, and gave an account of its chief physical and chemical properties. The liquid acetylene diiodide solidifies at —21° C. and boils at 185°. It has the percentage composition and molecular weight represented by the formula $C_2H_2I_2$, and is isomeric with the well known solid acetylene diiodide. The speaker announced the discovery of a new method of making the liquid acetylene diiodide, namely, by heating the solid compound to 260° in a sealed tube. The solid compound is thereby partially converted into the liquid compound. Similarly, if the pure liquid diiodide be heated to 260° in a sealed tube, on cooling down, the liquid will be found to have been partially converted into the solid compound. All the facts known indicate that these two iodides of acetylene are stereo-isomers, and that their configuration must be represented by the stereometric formulas.



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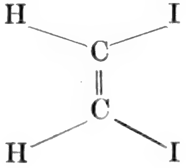

Since Dr. Keiser has found that the solid acetylene diiodide can be converted into fumaric acid, it would follow that the first of the two formulas would represent the solid acetylene diiodide and the second one the liquid diiodide. Further experiments upon these compounds are under way, and an attempt will be made to convert the liquid diiodide into maleic acid.

Dr. L. Bremer demonstrated some tests for glucose by means of anilin dyes, showing that nearly all of the "alkaline" anilin dyes, when rendered basic by the addition of sodium hydrate, become decolorized, or have their color greatly modified, on heating, in case glucose is present. The reactions shown were especially pretty in the case of methylene blue and safranine.

Professor F. E. Nipher announced that he had nearly completed preparations for the measurement of wind pressures on the sides of the main building of Washington University. The pressures are to be measured at various points along the west end of the building, having a width of about 50 feet, and along the north front, which is something over 200 feet in length. Silmultaneous measurements of wind pressure, and wind velocity and direction, will be made. The method used is that tested by him on the trains of the Illinois Central Railroad during the summer of 1897. The method was described in No. 1, Vol. VIII, of the Transactions of the Academy. An invitation was extended to members to visit the University and inspect the apparatus.

Professor H. Aug. Hunicke spoke briefly on some observations which he had recently made on the boiling temperature of hydrocarbons, from which it appeared that when T is the boiling temperature (absolute scale), ρ is radius of gyration of the molecule, and a is a constant, then $T^2 = a\rho$. This holds for the entire series of saturated hydrocarbons, including all isomers. The speaker stated that his observations had not yet been extended beyond the series indicated.

Messrs. Green, Nipher, and Hunicke were elected a committee for the nomination of officers for the year 1900.

December 18, 1899.

President Engler in the chair, twenty-seven persons present.

The Council reported the resignation of John T. Alden, and the death, not yet recorded, of Mr. A. W. Straub.

The nominating committee reported the following list of candidates for 1900: —

President	Edmund A. Engler.
First Vice-President	D. S. H. Smith.
Second Vice-President	M. H. Post.
Recording Secretary	William Trelease.
Corresponding Secretary	Joseph Grindon.
Treasurer	Enno Sander.
Librarian	G. Hambach.
Curators	G. Hambach, Julius Hurter, Hermann von Schrenk.
Directors	Amand Ravold, Henry W. Eliot.

Dr. Amand Ravold addressed the Academy on the necessity and means of filtering and otherwise purifying water, especially with reference to freeing it from bacteria for municipal purposes. The speaker explained the sand-bed filter system as used in Germany and England, and the American mechanical system, represented by two commercial devices. The Wormser filter plate was also described and its characteristics were considered.

One person was proposed for active membership.

REPORTS OF OFFICERS FOR THE YEAR 1899.

SUBMITTED JANUARY 8, 1900.

The President addressed the Academy as follows: —

It has always been the custom of the Academy to expect of its President some remarks of a more general character than those made by the other officers, with reference to the work which the Academy has been doing during the year past and with reference to its prospects for the future. I am glad to be able to report that the condition of affairs at the present time, although perhaps not as prosperous as all of us might desire, is still very satisfactory. During the year just closed, the Academy has held sixteen regular meetings, with an average attendance of twenty-one persons, at each of which some subject of scientific interest has been presented and discussed. The papers which have been presented have been of actual scientific value, as is shown by the fact that abstracts of them have generally appeared in *Science*, the exponent of scientific progress in the United States, and occasionally in *Nature*, the best record of current scientific work in the world, as well as in other journals; and the quality of the papers is also shown by the fact that three of those presented have been accepted by universities of good standing as theses for the degree of Doctor of Philosophy. Some of the papers presented have been deemed by the Council worthy of publication in the Transactions of the Academy, and I am glad to announce that during the year we have been able to carry out the programme decided upon last year, namely, the completion of a volume annually, by the publication for 1899 of Volume IX of the Academy's Transactions, which contains nine numbers in a volume of about 350 pages, illustrated by thirty-eight plates, two of them in color. Seven hundred and sixty-three copies of this volume have been distributed, as follows: 229 to members of the Academy, 140 to scientific societies in the United States, and 394 to foreign scientific societies with which the Academy stands in exchange relations, as is shown by the report of the Librarian.

The library has grown during the year by the addition of 745 numbers, the details being given in the Librarian's report, which makes the library at present a collection of 13,215 books and 9,430 pamphlets. While the number of additions to the library is not as great as during the year 1898, this should not be looked upon as a decrease in the rate of growth of the library, but only as a fluctuation, due to the fact that many of the publications of the societies with which we exchange are irregularly issued and irregularly distributed.

From the report of the Treasurer it will be seen that there is a considerable balance in the treasury after paying all expenses for the year, but it should be particularly noticed that of this balance $2,000.00 is a portion of the capital of the Academy which has heretofore been invested and producing an income, and which the Council will no doubt immediately reinvest, and that the remaining $239.13 of this balance is considerably less than the balance at the beginning of 1899. The report also shows that we have actually spent more money for the publication of Transactions than we have received during the year from the dues of members. Since we do not consider it desirable to curtail the publications of the Academy, it would appear that it is very desirable to increase the membership.

There has been no material change in the membership of the Academy during the year. At the close of last year we had 251 active members, and now we have enrolled 248 active members. We have lost 5 by death and 19 from other causes, making 24 in all. We have elected 15 resident and 6 non-resident active members, making 21, thus nominally decreasing the membership by 3; but as the losses include a considerable number of persons delinquent for many years, who have been dropped for non-payment of dues, and who were counted in last year's total, it would appear that the Academy has actually made a small gain in membership.

The same motives for effort on the part of the members of the Academy for the extension of its work in legitimate fields, for the increase of funds which will enable the Academy to carry out its purposes in the accumulation of a library and in securing a permanent home, the establishment of a museum, and the publication of good scientific matter, remain before us as prominently as last year. While some progress in this direction has been made and we have no reason to be discouraged, a careful consideration of the situation points to the necessity of active and earnest effort. Perhaps the best purpose to which this effort can be directed will be to increasing the active membership. There is no doubt that the larger the number of persons whom we can interest in the active work of the Academy, the greater will be our prospects for the early attainment of our desires, not to speak of the fact that we are dependent upon the income from the members for our actual living. This can be best seen by a consideration of the membership roll of the Academy, which shows the accessions of members from its organization.

From the reports received from the Secretary, to whom I am indebted for the information here presented, diagrams have been prepared which contain considerable information for those who study them.

Fig. 1 shows the total number of members who have been elected to membership previous to any date shown. The ordinate of the curve shows the total number of members who have been elected to membership previous to the year indicated at the foot of the ordinate. There is a general rise to the curve, and the curve is steeper in later years. The ordinate for the year 1899 shows that 845 different persons have been elected active members since the foundation of the Academy.

Fig. 2 shows the total number of members belonging at any one time. The curve is incomplete, and the incompleteness is shown on the drawing by the dashed portion of the line, owing to the fact that it was not thought of sufficient importance to make a very thorough search of the records of the Academy during those early years, and the general run of the curve was ascertained without the necessity of scrutinizing every line that had been written or printed; and since we are studying only general results, it is sufficiently accurate. The points are derived from the record. The straight line running over a period of years is equivalent to making the assumption that the change during that period was gradual; as a matter of fact, we know that it was not actually so. Near the beginning the Academy had 151 members. That was in 1860. The record previous to that time is in obscurity. The membership then dropped, up to the end of 1864. Probably the prin-

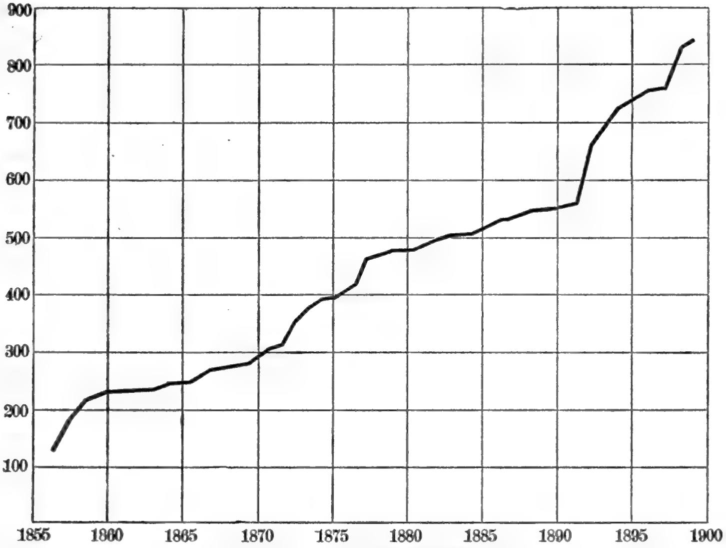

Fig. 1. Total Membership.

cipal cause for that drop was the Civil War, not so much because it took members away to the war, but because then those who did not go to the war were not particularly interested in the Academy, and the affairs of the Academy waned, and, as you see, the membership dropped to below 50. Then there were increases, as you see, and in the later years of the Academy

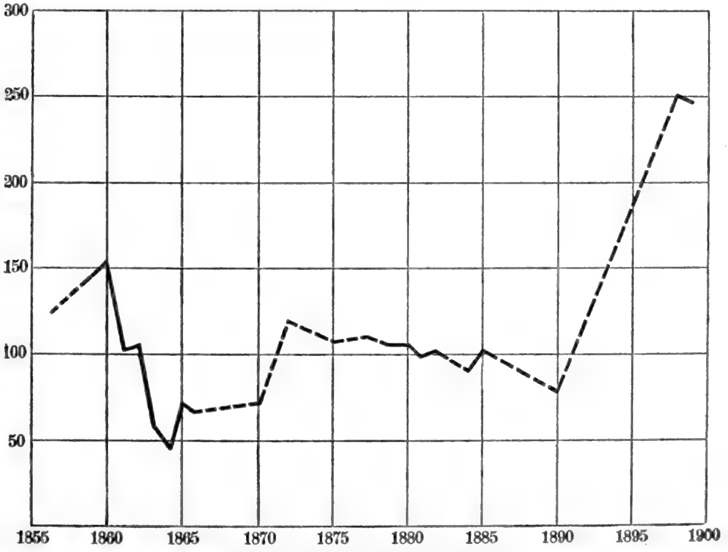

Fig. 2. Actual Membership.

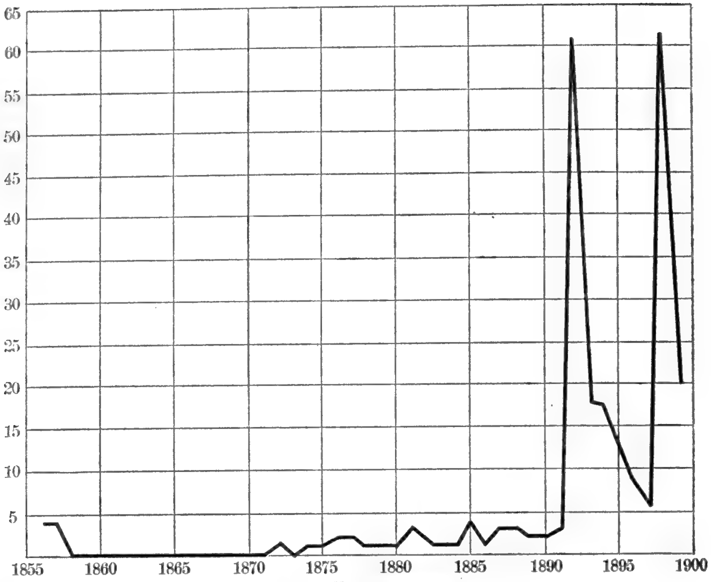

Fig. 3. Persistence.

the growth was more rapid; for the last year or so we have had about 250 members.

Fig. 3 shows the persistence of members, that is to say, how many members who were elected in any one year are at present members of the Academy. There are eight members still with us who were members in the first two years. We have no members in the Academy who were elected to membership during the period from 1856 to 1870. Of those elected from 1870 to 1890 there are a few, but not a large number. In 1891 there was a considerable increase in the membership, and 61 persons elected in that year are still members. From 1891 to 1897, there were comparatively few elected who are still members.

From these curves it appears that the most active periods in the Academy's growth have been from the beginning of 1856 to, say, the end of 1860 and from the beginning of 1891 to the end of 1894. The first of these periods corresponds to the enlistment of practically all the available men in St. Louis at that time, and the second, which really extends up to the present time, although for several years there was a period of relaxation, represents the response to efforts made by the members of the Academy in recent years to interest professional and business men in the affairs of the Academy. The curves also show that if this second period of vigorous growth had not taken place, we should now hardly have 100 members to carry on the Academy's work; 82 per cent of the members who are now enabling the Academy to do its work have been elected since 1891.

No doubt a complete discussion of these curves might bring out many interesting facts, and, were the data sufficient, it might be worth while to determine the curves, which would indicate the life of the Academy with greater accuracy; but without entering into any mathematical discussion of these curves, it must be apparent from the consideration of them that there is a necessity for unremitting activity to increase the membership, and that this activity should be directed on the one hand to those classes of persons, such as physicians, teachers, and others, from whom we can reasonably expect a greater interest and greater appreciation of the work which the Academy is attempting to do, in order that the persistence of their membership may be as long as possible. It is clear also that the Academy derives its principal resources from those persons who have been members only a comparatively short time and it will in all probability continue to do so; hence the desirability, indeed the necessity, on the other hand of inducing persons to join the Academy who, though not actively engaged in scientific work, appreciate its purposes and aims and are willing to help others to do the work, even if they persist for only a comparatively short time.

All honor, then, to that small body of scientific workers who have kept the Academy alive through many ups and downs; all honor too to that larger body of science-lovers who have provided the Academy, and we hope will continue to provide it in larger measure, with the wherewithal for doing its work.

The Treasurer reported as follows: —

RECEIPTS.		
Balance from 1898	$704 88	
Interest on invested money	405 00	
Membership dues	1,353 00	
Invested capital returned	2,000 00	$4,462 88
EXPENDITURES.		
Rent	$500 00	
Current expenses	274 05	
Publication of Transactions	1,449 70	2,223 75
Balance to 1900		$2,239 13
INVESTED FUND.		
Invested on security	$4,400 00	

The Librarian reported that during 1899 exchanges had been received from 246 societies, of which 11 were new. In all, 745 numbers were reported as having been added to the library, a decrease of 196 as compared with the preceding year. It was reported that during the year the Transactions of the Academy had been distributed to 533 societies or institutions, chiefly by way of exchange or donation.

On behalf of the curators, Dr. Hambach reported the receipt for the museum of two specimens of coral, presented by Mr. Julius Hurter, and added that the extensive meteorite collection of the Academy is now on exhibition.

STUDIES ON SUBTERRANEAN ORGANS. I. COMPOSITAE OF THE VICINITY OF MANHATTAN, KANSAS.*

A. S. Hitchcock.

The following notes include observations made during the fall of 1898, and also some made while preparing Bulletin No. 76, of the Kansas Experiment Station.

So far as the duration of the underground parts is concerned the plants fall naturally into three categories, annuals, biennials and perennials.

The following are annuals: *Erigeron Canadensis*, *E. divaricatus*, *E. strigosus*, *Gnaphalium polycephalum*, *Iva ciliata*, *I. xanthiifolia*, *Ambrosia trifida*, *A. artemisiaefolia*, *Xanthium Canadense*, *Eclipta alba*, *Helianthus annuus*, *H. petiolaris*, *Coreopsis involucrata*, *Bidens frondosa*, *B. connata*, *B. chrysanthemoides*, *B. cernua*, *Dysodia chrysanthemoides*, *Erechtites hieracifolia*, *Sonchus asper*. Most of these are found in low ground, waste places, or cultivated soil, and would be classed as mesophytes. A few are hydrophytes or at least lovers of damp places, *Eclipta*, *Coreopsis*, and the last three species of *Bidens*. Two are lovers of sandy soil (psammophytes), *Gnaphalium* and *Helianthus petiolaris*. Three are prairie xerophytes, *Erigeron divaricatus*, *E. strigosus* and *Dysodia*. The last is frequently abundant on limestone bluffs and is the only annual that is properly a member of such communities.

The following are apparently biennials, though more observations are needed upon some of the species to determine this point: *Grindelia squarrosa*, *Arctium Lappa*, *Cnicus altissimus*, *Hieracium longipilum*, *Prenanthes asper*, *Lactuca Canadensis*, *L. Ludoviciana*, *L. Floridana*. *Cnicus altissimus* produces the first year a fleshy tap-root and often several lateral tuberous roots in addition. *Grindelia*, *Lactuca* and

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* Presented to The Academy of Science of St. Louis, January 23, 1899.

probably others germinate in the fall, producing rosettes which live over winter. *Arctium*, *Cnicus*, *Lactuca Canadensis* and *L. Floridana* are mesophytes growing in shaded places or wastes. The others are prairie xerophytes.

The perennials may be divided into three series; those which form crowns, those which propagate by stems, those which propagate by adventitious buds upon roots.

Crown formers. Under this head are included plants which have no well marked adaptation for vegetative propagation, but in which the base of the stem or stems lives through the winter. The new shoots are produced from buds upon the base of these stems. Sometimes the crown is short and compact upon a well-marked tap-root.

This is well illustrated by *Kuhnia eupatorioides*, *Lepachys columnaris*, and our four species of *Liatris* (*L. punctata*, *L. scariosa*, *L. squarrosa*, *L. pycnostachya*). In such cases it is difficult to tell whether the buds are axillary or adventitious. Those mentioned are all xerophytes. In the first two examples the root is long and slender. In *Liatris* it forms a peculiar woody corm-like body. The structure of this root is interesting as showing its adaptation to xerophilous conditions. In *L. punctata* the outer part of the root is protected by a layer of cork several cells thick. The bulk of the interior is made up of parenchyma cells well stored with water. This water can be easily forced from a cut root with a little pressure even in the driest weather. The outer region of the root is well supplied with strands of sclerenchyma fibers. These strands lie in radial rows continuous in xylem and phloem. In cross-section they are circular or oblong (in a radial direction), and are separated from each other by wide cushions of parenchyma cells. In the xylem there is a comparatively thin strand of pitted vessels lying along the inner side of the sclerenchyma strand. These strands of mechanical tissue become thinner and farther apart towards the center until they disappear and the whole interior of the root is made up of the water tissue. Maceration with Schulze's solution shows the sclerenchyma fibers to be comparatively short, pointed and often branched at the ends, with numerous nearly straight canals radiating from the very thin cell cavity.

The parenchyma of the pith is abundantly stored with inulin, while the outer part of the phloem is well supplied with an oil which was not determined. There is no starch or tannin.

In another series the crown increases in length each year, the inflorescence being axillary and the leaves forming a rosette. In *Troximon cuspidatum* the crown is simple, while in *Taraxacum officinale* it is branched. In the latter and probably the former the crown is drawn down into the ground each year by the contraction of the root.

In a third series no strong root is formed, the root system consisting of fibers. At the base of the first stem, buds are formed which produce shoots the succeeding year. This goes on from year to year. The crown thus formed consists of a mass of stems, the bases of old shoots. This is one of the largest categories. In *Aster sericeus* the large white buds that are to form next year's shoots can be seen closely appressed to the old stem. If the new shoots grow obliquely or horizontally for a short distance before emerging from the soil a matted crown is formed consisting of intertwining stem bases, which might with equal propriety be called short rhizomes. *Vernonia Baldwinii* forms such a crown. Thus we find a gradual transition from the simple crown of *Aster sericeus* to rhizome production. In some species the connection between the old stems soon rots away and the crown is easily separated into its component parts. To the crown formers of this third series belong: *Vernonia Baldwinii*, *V. fasciculata*, *Eupatorium altissimum*, *E. perfoliatum*, *E. ageratoides*, *Solidago rigida*, *S. speciosa angustata*, *S. nemoralis*, *Aster azureus*, *A. sericeus*, *A. Drummondii*, *A. laevis*, *Silphium integrifolium*, *Heliopsis scabra*, *Echinacea angustifolia*, *Actinomeris squarrosa*, *Hymenopappus corymbosus*, *Chrysanthemum Leucanthemum*.

Silphium laciniatum produces strong woody root-like rhizomes. This needs to be investigated further, but it seems that when a branch of the rhizome has produced a flowering shoot it ceases to grow. But branches which produce a rosette of leaves form a strong bud at the apex. This bud appears partly buried in the substance of the rhizome. How long these branches form rosettes before they finally terminate in a flowering shoot I have not ascertained. An examination of the internal structure of this rhizome shows that below an indefinite corky layer is a layer of stone cells (three or four cells thick). These stone cells are about three times as long as wide, with very much reduced cavity. There are no strands of sclerenchyma. The central portion of the rhizome contains large quantities of inulin. *Artemisia dracunculoides* forms a large woody crown similar to shrubs, consisting of stems upon a woody branched root.

Of the crown forming species mentioned, *Vernonia fasciculata*, *V. Baldwinii* (transition to xerophyte), *Eupatorium perfoliatum*, *E. ageratoides*, *Aster Drummondii*, *Actinomeris*, *Chrysanthemum*, *Taraxacum* are mesophytes, though some are found more or less frequently in xerophyte communities. All the others are xerophytes growing on prairie and limestone hills. A few prefer limestone hills, such as *Echinacea*, *Troximon* and *Hymenopappus*.

Propagation by stolons. The only examples of this are our two Antennarias, *A. plantaginifolia* and *A. campestris*. The former grows in dry open woods and the latter is common on the prairie. Slender stolons are sent out just above the surface. These end in rosettes which form new plants. If the stolons are short they would be called offsets.

Propagation by rhizomes. As was said in a preceding paragraph there is a transition from the formation of a loose crown of intertwined stem bases to the production of short rhizomes, as in *Helianthus Maximiliani*. In *Helianthus tuberosus* tubers are formed at the ends of the rhizomes. *Achillea Millefolium* forms summer rhizomes, each producing a rosette of leaves. The following are mesophytes growing in moderately moist soil: *Solidago serotina*, *S. Canadensis*, *S. Lindheimeriana*, *S. lanceolata*, *Aster paniculatus*, *Helianthus grosse-serratus*, *H. tuberosus*, *H. hirsutus*. The others are xerophytes. *Solidago Missouriensis*, *Aster oblongifolius rigidulus*, *A. multiflorus*, *Helianthus rigidus*, *Achillea Millefolium* and *Artemisia Ludoviciana* prefer prairie, while *Helianthus Maximiliani* prefers limestone bluffs. The latter is the only rhizome forming species which is at all common in stony soil and as was said the rhizomes are so short that the plants appear in bunches. *Artemisia Ludoviciana* grows more or less in sandy soil.

Propagation from running roots. A few species form adventitious buds upon creeping propagating roots. These are *Ambrosia psilostachya*, *Cnicus undulatus* and *Lygodesmia juncea*. It is well known that *Taraxacum officinale* produces buds upon the cut roots although they do not ordinarily form spontaneously, and some of the other crown forming species may also have this power. This has not been investigated. All the three species mentioned above are prairie xerophytes though *Ambrosia* is also frequent in sandy soil. *Cnicus* produces tuberous roots and the buds may be formed on these or on the slender roots.

Before drawing conclusions as to the relation between the structure of the subterranean organs and the environment of the plant other groups must be investigated.

Below is given a reference list of our *Compositae*, with brief notes on subterranean parts, arranged according to Gray's manual.

Vernonia Baldwinii, Torr. A crown of short knotty tangled rhizomes. Prairie and more or less in moist open soil.

V. fasciculata, Michx. Similar to above. Low ground.

Eupatorium altissimum, L. Close crown with buds along base of old stems. Along edge of woods, hedges, on prairie and often on rocky soil.

E. perfoliatum, L. Crown a creeping horizontal rhizome with branches. Wet places.

E. ageratoides, L. Crown small with numerous fibrous roots, easily separating into parts. Woods.

Kuhnia eupatorioides, L. Crown supported by a long taproot. Prairie and stony bluffs.

Liatris squarrosa, Willd. Crown from a corm-like woody globose root. Sandy soil.

L. punctata, Hook. Root similar. Prairie.

L. scariosa, Willd. Root similar. Prairie and stony bluffs.

L. pycnostachya, Michx. Root similar. Base of stems fibrous-coated. Moist prairie.

Solidago Lindheimeriana, Scheele. Short rhizomes. Open woods and wooded stony bluffs.

S. speciosa angustata, T. & G. Crown consisting of base of old stems. Prairie.

S. Missouriensis, Nutt. Slender rhizomes. Prairie.

S. serotina, Ait. Slender rhizomes. Thickets, fence-rows and moist open ground.

S. Canadensis, L. Rhizomes stouter than the preceding. In similar situations to the preceding and more or less on prairie.

S. nemoralis, Ait. Loose crown of stem bases. Prairie and sterile soil.

S. rigida, L. Close crown of stem bases. Prairie and sterile or stony hills.

S. lanceolata, L. Rhizomes. Moist soil.

Aster oblongifolius rigidulus, Gray. Rhizomes. Prairie and sterile hills.

A. sericeus, Vent. Small compact crown. Prairie and stony hills.

A. azureus, Lindl. Loose crown. Often forming rosettes of leaves in fall. Open woods and along the edges of woods.

A. Drummondii, Lindl. Loose crown of stem bases. Often producing rosettes of cordate leaves in the fall. Open woods.

A. laevis, L. Loose crown similar to preceding. Similar situations to *A. azureus*.

A. multiflorus, Ait. Rhizomes. Prairie.

A. paniculatus, Lam. Rhizomes. Moist places.

Erigeron Canadensis, L. Annual. Waste places and open woodland.

E. divaricatus, Michx. Annual. Prairie.

E. strigosus, Muhl. Annual or biennial (winter annual). Prairie.

Antennaria plantaginifolia, Hook. Stolons. Dry open woods.

A. campestris, Rydb. Stolons. Prairie.

Gnaphalium polycephalum, Michx. Annual. Sandy fields.

Silphium laciniatum, L. Thick branched rhizome supported by an equally thick root forming an open crown. Prairie and stony hills.

S. integrifolium, Michx. Open crown of half-inch-thick stems forming rosettes in fall. Prairie and thickets.

Iva ciliata, Willd. Annual. Moist ground.

I. xanthiifolia, Nutt. Annual. Open low ground.

Ambrosia trifida, L. Annual. Low ground.

A. artemisiaefolia, L. Annual. Cultivated soil and waste places.

A. psilostachya, DC. Buds on creeping roots. Prairie, open woods and sandy soil.

Xanthium Canadense, Mill. Annual. A weed in cultivated soil.

Eclipta alba, Hassk. Annual. Near river banks and other wet places.

Heliopsis scabra, Dunal. Small crown with numerous fibrous roots. Borders of woods.

Echinacea angustifolia, DC. Crown branched, supported by a strong root. Stony bluffs and less frequently on prairie.

Lepachys pinnata, T. & G. Crown of numerous stems but no long root. Many rosettes are thrown up from this crown which probably produce flowering stems the second year. Borders of woods.

L. columnaris, T. & G. Crown supported by a long tap-root. Prairie.

Helianthus annuus, L. Annual. Fields and open ground.

H. petiolaris, Nutt. Annual. Sandy soil.

H. rigidus, Desf. Rhizomes. Prairie.

H. grosse-serratus, Mart. Rhizomes. Moist places.

H. Maximiliani, Schrad. Rhizomes shorter and thicker than the preceding. Stony hills and prairie.

H. hirsutus, Raf. Rhizomes. Dry open woods.

H. tuberosus, L. Rhizomes ending in tubers. Woods, fence-rows and low ground.

Actinomeris squarrosa, Nutt. Crown of short rhizomes or the horizontal bases of the stems. Woods.

Coreopsis involucrata, Nutt. Annual. Springy places.

Bidens frondosa, L. Annual. Fields and low ground.

B. connata, Muhl., *B. cernua*, L., *B. chrysanthemoides*, Michx. Annual. Wet places.

Hymenopappus corymbosus, T. & G. Crown single. New rosettes come from the axils of the old leaves, thus broadening the crown. Stony hills.

Dysodia chrysanthemoides, Lag. Annual. Dry open ground.

Achillea Millefolium, L. Rhizomes forming plants the same year. Rhizomes short, sometimes mere offsets. Prairie.

Chrysanthemum Leucanthemum, L. Crown compact. Meadows and pastures.

Artemisia dracunculoides, Pursh. A large woody branched crown. Moist sandy soil.

A. Ludoviciana, Nutt. Slender rhizomes. Prairie.

Erechtites hieracifolia, Raf. Annual. Moist open woods and waste places.

Arctium Lappa, L. Biennial. Waste places.

Cnicus undulatus, Gray. Buds from creeping roots or from the tuberous roots. Prairie.

C. altissimus, Willd. Biennial, forming the first year a fleshy root or lateral tuberous roots. Open woods and fence rows.

Lygodesmia juncea, Don. Buds on creeping roots. Prairie or clay banks.

Troximon cuspidatum, Pursh. A vertical caudex, usually simple. Prairie or stony hills.

Taraxacum officinale, Weber. Vertical tap-root supporting one or more caudices. Root forms buds when cut. Waste places.

Lactuca Canadensis, L. Biennial. Low ground, borders of woods and waste places.

L. Ludoviciana, DC. Biennial. Prairie.

L. Floridana, Gaertn. Biennial. Woods.

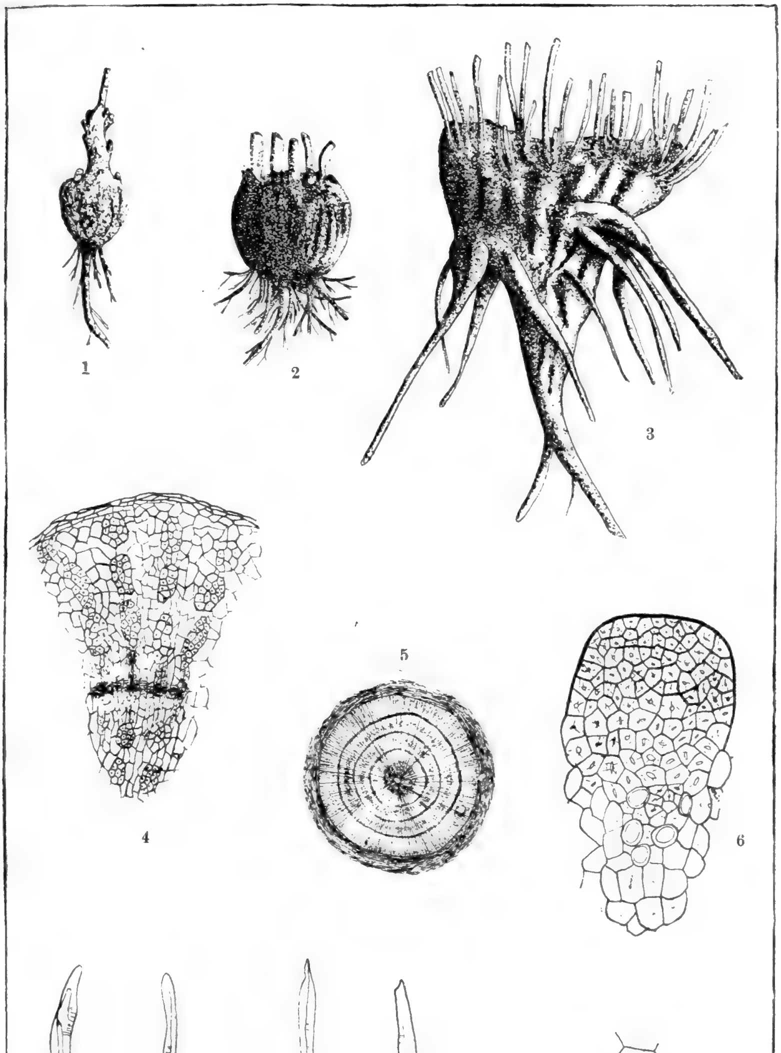
Sonchus asper, Vill. Annual. Waste places.

EXPLANATION OF ILLUSTRATIONS.

PLATE I.

Liatris punctata. 1, 2, 3, Roots taken at successive stages of growth, natural size. 4, Cross-section through phloem and part of xylem, showing sclerenchyma strands and cambium. 5, Cross-section through old root, showing annual rings in xylem. 6, Cross-section of sclerenchyma strand, showing ducts. 7, Four sclerenchyma fibers. 8, Three fibers in cross-section.

Issued February 18, 1899.



LIATRIS PUNCTATA.

KINDERHOOK FAUNAL STUDIES. I. THE FAUNA OF THE VERMICULAR SANDSTONE AT NORTHVIEW, WEBSTER COUNTY, MISSOURI.*

STUART WELLER.

The faunas of the Kinderhook formations in the Mississippi Valley have long been neglected. Lying as they do on the border line between the Devonian and Carboniferous periods, they present problems of extreme interest to the student of paleontologic geology. The Kinderhook epoch was a time of transition, a period of change which ushered in the long period of quiet which constituted the Osage epoch of Mississippian time.† Very naturally, because of the progressive changes in the physical conditions of the time, the Kinderhook fauna is more or less diverse in its characters. It is not one single fauna, but is constituted of many faunulae, each one of which is more or less restricted both in time and place.

In order to work out the relationships existing between the various local assemblages or local societies of organisms which were living during Kinderhook time in the present Mississippi valley, it is our purpose to make a careful study of as many separate ones of these fossil societies as can be secured. In each one of these studies the fossils from a single horizon at a single locality will be discussed, that is, those organisms which we know actually lived together and formed a social community. All the species, both the old ones and those recognized for the first time, will be described and illustrated as fully as possible, so that direct comparisons between the faunal groups may be made by the student without his having to undertake a laborious investigation through many scattered

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* Presented by title to The Academy of Science of St. Louis, April 3, 1899.

† See Stuart Weller, Classification of the Mississippian Series. Jour. Geol. **6**: 303–314. (1898).

books and papers. Comparisons and correlations will also be made in each case, between the fauna under discussion and those in other localities.

In the present paper the fauna of the Vermicular Sandstone in the neighborhood of Northview, Webster County, Missouri, is described. This formation was so named by Swallow* in 1855, because of the innumerable worm burrows penetrating it in every direction. In the southwestern part of Missouri, in Green, Webster and Polk counties, the formation is very constant in its lithologic characters, and obtains a thickness of about 25 feet. It is a buff-colored, fine-grained sandstone, sometimes changing to a bluish color. The worm burrows by which the rock is penetrated throughout, are filled with less indurated material usually a little more highly-colored than the rock itself. The weathered surfaces of the formation can always be recognized with the greatest ease, because of these burrows whose soft filling is easily removed on exposure, leaving the tortuous passages clearly visible (see figure 1, plate VI). The formation is underlaid by a soft bluish clay shale, which easily disintegrates from beneath the sandstone; and because of this it is not usual to find the Vermicular Sandstone forming out-cropping ledges to any great extent. The slopes where the shales and sandstones both occur are usually covered with broken masses of the latter, which have slidden down from above.

The formation is usually almost wholly barren of organic remains except the worm burrows and a species of *Spirophyton*. From among all the localities examined in Green, Polk and Webster counties, only at Northview have fossils been found abundantly. The fossils described in the present paper were all collected within the square mile of territory lying directly south of Northview. Some of the specimens were secured from the foundation of an old mill, in blocks of sandstone which originally came from a nearby abandoned quarry, and most of these specimens have been changed to a bright red color by the heat of the fire which destroyed the mill.

The manner of preservation of the fossils at Northview is rather peculiar. In not a single instance has a calcareous

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* First and Second Ann. Repts. Geol. Surv. Mo. 103 (1855).

shell been observed, and yet the fossils are not strictly internal casts for there is no cavity remaining from which the shell itself has been dissolved. Furthermore, many of the specimens preserve the most delicate surface markings. From the nature of the fossils it seems as if the calcareous substance of the shells was removed soon after they were buried, before the sediments were consolidated, and that the cavities thus formed were closed by pressure. In this manner the delicate external markings have in some cases been perfectly preserved, while in other specimens it is the form of the interior which remains. Now, in the consolidated rock, these planes along which the cavities were closed, split more easily than the rock itself, and consequently we are enabled to secure the form of the fossils.

The fact that worm burrows seem to penetrate fossil shells in some cases, indicates further that the shells themselves were removed before the sediments were consolidated, when they were still soft enough to allow the worms to burrow through them in all directions.

This manner of occurrence may account for the apparent general absence of fossils from the formation. They may have been everywhere abundant originally, but with the removal of the shells, and the consolidation of the sediments, all traces of them may have been usually destroyed. In only some favored localities, such as Northview, were there present some conditions not fully known to us, which prevented the sides of the cavities left by the removal of the shells, from adhering as closely as the other portions of the matrix.

DESCRIPTIONS OF SPECIES.*

COELENTERATA.

ZAPHRENTIS sp.

Among the Northview fossils two small specimens of corals have been observed which apparently belong to this genus,

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* From these descriptions the bibliographic references have been omitted. For these the reader is referred to Bulletin 153, U. S. Geological Survey, "A Bibliographic Index of North American Carboniferous Invertebrates", by Stuart Weller. Washington. 1898.

although they are too imperfectly preserved for specific identification or description. The largest one has a diameter of 8 mm.

ECHINODERMATA.

The impressions of numerous detached joints of crinoid stems are scattered throughout the sandstone, but in no instance has any portion of a calyx been observed.

VERMES.

SCALARITUBA MISSOURIENSIS n. gen. and sp.
Pl. VI. f. 1.

The Vermicular Sandstone is named from the innumerable worm burrows which penetrate it in every direction, there rarely being a distance of more than two or three centimeters between burrows in any direction upon any broken surface of the rock. These burrows are 2–4 mm. in diameter, subcylindrical in form, never straight for more than a few centimeters, curving in all directions, and marked by transverse ridges situated at distances of one or two millimeters. These ridges were evidently formed by the worm as it forced itself forward through the mud of the sea-bottom, the posterior extremity of the animal pushing up a small ridge of the plastic material behind to serve as a brace while the anterior extremity was forced forward. If this was the method of formation of these ridges, then the direction of progress of the worm itself was always away from the concave side of the ridges. The burrows are now filled with material similar to that which surrounds them, but it is softer and of finer texture so that on weathered surfaces the burrows become very conspicuous by reason of the removal of this softer material. Upon freshly broken surfaces of the rock, however, the burrows are not conspicuous, but they may be detected by their slightly different color, and by their softness.

These burrows seem to be different from any of the previously described worm burrows, and as they are such a conspicuous feature of this formation, it seems that they are entitled to a distinctive name, and they are therefore designated *Scalarituba missouriensis.*

MOLLUSCOIDEA.

BRACHIOPODA.

ORTHOTHETES CHEMUNGENSIS (Conrad).

Shell more or less semi-elliptical in outline, unsymmetrical, the greatest width usually being along the hinge-line; both valves often distorted to a greater or less extent because of the attachment of the living shell. Pedicle valve usually moderately concave but sometimes nearly flat, elevated at the beak and around the margin, beak often distorted. Brachial valve convex, the greatest convexity usually at about the center, somewhat compressed towards the cardinal extremities. Surface of both valves marked by radiating costae which usually increase by intercalation with some regularity, and by more or less prominent lines of growth. Sometimes the whole surface is covered by very fine concentric ridges which are most prominent between the radiating costae.

Remarks. Orthothetes chemungensis is one of the most variable species of brachiopods known, the great variation in form being due, perhaps, in part, to the attachment of the shell during life to some extraneous object by the point of the beak. A good idea of the great degree of variation of the shell may be had by examining Hall's* illustrations of the species from the Chemung group of New York. There is almost no character of the species which can be said to be constant, except its great variability. Among the Northview fossils there are numerous specimens, all in a more or less fragmentary condition, which are identified with this species. Some of them may be compared with *O. desideratus* Hall and Clarke, from the Waverly group of Ohio, but they constantly differ from that species in the less convex brachial valve, the less concave pedicle valve, and in the greater relative length of the hinge-line. None of the specimens are perfect enough to be worthy of illustration.

SCHIZOPHORIA SWALLOVI (Hall).

Pl. IV. f. 7.

The genus *Schizophoria* is abundantly represented in the Devonian faunas west of the Mississippi River, and in the

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* Pal. N. Y. 4. *pl. 10.*

upper Devonian faunas of New York. It also continues into the faunas of the lower portion of the Mississippian series. In the Devonian faunas various species are recognized, *S. iowensis*, *S. tulliensis*, *S. impressa*, etc., but they all seem to merge the one into the other, the real specific lines having never yet been drawn with entire satisfaction. A part or all of them should perhaps be included in the one European species *S. striatula.* The Carboniferous specimens are usually called *S. swallovi*, though this species is perhaps indistinguishable from the European *S. resupinata*.

A comparison of a large number of the later Devonian representatives of the genus and the early Carboniferous ones, seems to indicate that they all belong to one common stock which exhibits local variations both in time and space. With the progress of time the shells exhibit a tendency to increase in size, a tendency which is apparently independent of the environment in which the organisms lived. Not that the smallest ones are always the earliest in time, but that the average size of the earlier ones is less than the average size of the later ones. The specimens of *S. tulliensis* illustrated by Hall * are all under 30 mm. in breadth, the average being about 28 mm., and his illustrations may be taken as representing about the average size of the species. On the other hand, *S. swallovi* in the Osage fauna sometimes attains a width of 60 mm., the average probably being between 40 and 50 mm. That this difference is not dependent upon the environment is shown by the fact that in the Chemung fauna, the highest of the Devonian faunas in New York, the species *S. impressa* grows to a much larger size than does *S. tulliensis* at the base of the Upper Devonian. One of the specimens illustrated by Hall † is between 39 and 40 mm. in breadth, and other specimens have been observed still larger, this in spite of the fact that the Chemung environment was very different from the environment in which the large Osage representatives lived, and in spite of the fact that the Chemung environment was not particularly favorable to brachiopod life.

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* Pal. N. Y. **4.** *pl. VII. f. 5 a–k.*

† Pal. N. Y. **4.** *pl. VIII. f. 11–19.*

Another change which took place during the life history of this group of brachiopods was the reduction of the mesial sinus in the pedicle valve. Among the Devonian representatives the sinus was always present and sometimes it was developed to an extreme degree, while in the latest representatives the sinus is never conspicuous and is sometimes entirely obsolete.

The Kinderhook representatives of this group of shells exhibit, in general, an intermediate condition, and the Northview specimens are no exception. The largest and best preserved specimen is 37 mm. in breadth and the sinus is but moderately developed. It is referred to the Carboniferous species *S. swallovi* or *S. resupinata*, although phylogenetically it is probably between that species and some of those of Devonian age. Of the Devonian species it approaches most closely to *S. impressa* of the Chemung, but the sinus in *S. impressa* is on the average much more strongly developed than in the Northview specimens.

RHIPIDOMELLA BURLINGTONENSIS (Hall).

Pl. IV. f. 13.

This species is present in almost every Kinderhook fauna, and it is one of the commonest ones at Northview. It is closely allied to the European *R. michelini*, but a comparison of American specimens from various localities and horizons with European specimens and illustrations, seems to indicate that the more prominent beak is a constant character of *R. burlingtonensis* by which it may be separated from *R. michelini*. The species is allied to the Devonian *R. vanuxemi*, and it is entirely probable that the two forms are genetically related.

CHONETES ILLINOISENSIS Worthen.

Pl. IV. f. 10.

Chonetes multicosta Winchell, described from the "Yellow Sandstone" and "the base of the Burlington limestone" at Burlington, Iowa, is perhaps not distinguishable from *C. illinoisensis*. It is described as having 180–200 radiating costae, and two or three cardinal spines upon each side of the beak nearly at right angles to the hinge-line, *C. illinoisensis* on the other hand is described as having 100–120 or more radiating costae, and five or six oblique spines upon each side of the beak. The descriptions of *C. illinoisensis* do not state how many *more* than 120 costae there may be in that species, but some specimens which have been observed from the Osage fauna, are certainly *C. illinoisensis*, and they possess as many as 200 costae, so that the number of costae cannot be taken as a good character for the separation of the two species. The cardinal spines, however, might well furnish a distinguishing character if it could be observed, but unfortunately, in the majority of cases the spines are not preserved in specimens of *Chonetes*. Furthermore, the number and direction of the cardinal spines is a character in which one may be easily mistaken unless it be observed in a considerable number of specimens. Therefore, in consideration of the facts that *C. multicosta* has never been illustrated, and that apparently no one except the author of the species has ever been able to identify it, it seems best to consider the two species *C. illinoisensis* and *C. multicosta* as synonyms. It is possible, of course, that at some future time, when Winchell's types are illustrated, the two species will be shown to be distinct, but the short description of *C. multicosta* which has been published, is not sufficient to make this at all certain.

A shell which is referred to *C. illinoisensis* is a common species in the Northview fauna. None of the specimens have the cardinal spines preserved, and the number of radiating costae is from 150–175. In general form and size they are not different from the specimens of *C. illinoisensis* which are so abundant in the Osage fauna, but they are usually much flattened by pressure.

CHONETES sp. — Cf. C. TUMIDUS Herrick.

Besides the specimens referred to *Chonetes illinoisensis*, there are in the Northview fauna several specimens of another species of the same genus. These differ from the former in their smaller size, their highly convex pedicle valves, their coarser and smaller number of radiating plications, and their more extended hinge-line. Only a few specimens have been observed, and these are all of them more or less imperfectly preserved, so that a complete description of them cannot be given. In general form they seem to resemble *C. tumidus* Herrick, from the Waverly group of Ohio, more closely than any other species, though they apparently have a smaller number of radiating plications than fifty, the number given for that species. It is possible that with sufficiently well-preserved specimens, these shells would be found to belong to an undescribed species, but for the present they will be compared with *C. tumidus*.

PRODUCTELLA CONCENTRICA Hall.?

A single imperfect specimen of the interior of the brachial valve of a *Productella* is identified with some doubt as *P. concentrica*. It differs from Hall's * illustration of this species chiefly in its greater size, the breadth being about 23 mm. while the figure of *P. concentrica* is only a little more than 12 mm. wide. Aside from the difference in size there seem to be no essential differences between the two shells.

PRODUCTUS sp.

Several fragments of a species of this genus are present in the Northview collection, but their condition of preservation is not such as to allow of their specific identification. The best preserved specimen, and perhaps also the others, is of the type of *P. cora*, and it is possible that it should be identified with *P. laevicostus*.

SPIRIFER MARIONENSIS Shumard.

Pl. IV. f. 12.

Shell subsemicircular in outline, the width about one-half greater than the length, the extremities of the hinge-line often extended into mucronate points, the two valves nearly equally convex. Pedicle valve gibbous in the umbonal region, more or less compressed toward the cardinal extremities, the greatest convexity back of the middle; area narrow with nearly parallel sides, extending to the hinge extremities; beak pointed and incurved; the sinus well defined, narrow and angular at the beak but becoming broad and shallow towards

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* Geol. Iowa. 1^2. *pl. VII. f. 3.*

the front of the shell and occupied by bifurcating plications which are about six in number at the front margin. Brachial valve regularly convex except for a slight compression towards the cardinal extremities, the greatest convexity at a point on the median line between the beak and the middle of the shell; the mesial fold but slightly elevated above the general level of the valve, marked by two plications at the beak which bifurcate and increase to from four to six at the anterior margin. Surface of each valve marked by from fifteen to twenty-two rounded plications upon each side of the fold and sinus, with a few of those nearest the fold and sinus sometimes bifurcating in an irregular manner. Aside from the plications the shell is marked by fine concentric lamellose striae or lines of growth.

Remarks. This species exhibits a considerable range of variation in some of its characters. The largest specimens attain a width along the hinge-line of over 45 mm. while the smaller ones are scarcely 20 mm. in width. There is also great variation in the coarseness of the plications, and in the bifurcation of the first five or six on either side of the fold and sinus. In some individuals these plications are entirely simple, while in others they bifurcate at almost any point between the beak and the front margin. There is also a variation in the cardinal extremities, some of them being almost rectangular, while in others they are produced into mucronate points. The most reliable character for the identification of the species is the low mesial fold of the brachial valve, and the narrow area with subparallel sides. In some specimens there is almost no elevation of the fold above the general level of the shell, the fold being bounded by two furrows a little deeper than the others, while in other individuals the fold has a moderate elevation.

SPIRIFER. — Cf. S. STRIATIFORMIS Meek.

A few specimens of a species of *Spirifer* different from *S. marionensis*, have been found in the Northview fauna. Only pedicle valves have been observed and none of these are sufficiently well preserved to allow of a full description. They differ from *S. marionensis* in being larger than the average size of that species, in being more gibbous with a less sharply defined mesial sinus, and with a larger number of plications nearly all of which bifurcate near the beak. The shell seems to approach most nearly to *S. striatiformis* Meek, and is provisionally identified with that species. One of the specimens resembles somewhat closely Hall's figure of *S. subrotundatus* (Geol. Surv. Iowa **1**². *pl. VII. f. 86*) described from the "Chemung Group" at Burlington, Ia.

SPIRIFER sp.

This species is represented in the collection by numerous fragments, but by no specimens sufficiently well preserved to allow a complete description and illustration. It has the general form of *S. suborbicularis* from the Osage fauna, but it is always much smaller, rarely or never growing to be more than 20 mm. in length. It is more or less subcircular in outline, with a short hinge-line; the fold and sinus are well defined to the beak and are nearly or quite free from plications; the plications on the sides of the shell are simple, rather broad, and flattened. The species occurs in other Kinderhook faunas, both older and younger than the present one, and will be more fully described and illustrated at another time.

SPIRIFER sp.

Several more or less imperfect specimens have been found, of a small species of this genus about 10 or 12 mm. in breadth, having an elongate hinge-line with angular or mucronate cardinal extremties, a smooth well-defined sinus and simple plications on the sides of the shell. It has not been possible to identify it with any described species, and it is consequently left until more perfect specimens can be secured, for description and illustration.

SPIRIFERINA sp.

Several specimens altogether too imperfect for description or illustration, probably belong to this genus. They have the general form of other members of the genus, and are characterized by their subangular plications and their conspicuous concentric lamellae of growth.

SYRINGOTHYRIS CARTERI (Hall).

Pl. IV. f. 5, 6.

Shell subsemielliptical in outline, the width about three-fourths greater than the length, the cardinal extremities usually nearly rectangular. The brachial valve convex, sometimes becoming gibbous, the beak incurved, the mesial fold regularly rounded without plications. Pedicle valve subconical in form, the mesial sinus well defined, the cardinal area arched, its height about two-fifths the breadth of the shell, the delthyrium large, the sides forming an angle of about 38 degrees. Surface of each valve marked by about fifteen simple, rounded plications on each side of the fold and sinus; in the casts, these plications become less and less distinct from the center to the cardinal extremities of the shell, where they become obsolete with still room for three or four additional ones which would probably be distinguishable upon the exterior of a perfectly preserved shell. Besides the plications, the shell is marked by concentric lines of growth, and the area of the pedicle valve by both vertical and transverse striae.

Remarks. Although the characteristic canaliferous plate of *Syringothyris* has not been observed in the Northview specimens, nor the punctate shell structure, they are placed with little or no hesitation in this genus because of the high cardinal area and the unplicated fold and sinus. Two well preserved specimens of the brachial valve, besides fragments, and one imperfectly preserved ventral valve showing the cardinal area, have been observed, and these agree closely with the original description of *S. carteri*.

AMBOCOELIA PARVA n. sp.

Pl. IV. f. 1–4.

Shell from 3 to 5 mm. in width. The length a little less than the width, subelliptical or subcircular in general outline, the hinge-line shorter than the greatest width of the shell. Pedicle valve gibbous with the umbo highly elevated, the beak obtuse and moderately incurved, the cardinal area not sharply defined. Surface smooth except for the sharply impressed, groove-like mesial sinus. Brachial valve unknown.

Remarks. This species resembles a diminutive *A. umbonata*, but does not have the sharply defined cardinal area which is characteristic of that species. It also resembles, but to a less degree, *A. minuta*, differing from it in its larger size and its sharply impressed groove-like mesial sinus.

ATHYRIS LAMELLOSA (Léveillé).

Pl. IV. f. 8.

An examination of specimens from various localities in the Kinderhook group has led to the conclusion that *Athyris hannibalensis* and *A. lamellosa* are one and the same species. From near Sulphur Springs, Mo., at the same locality or at least from the same horizon at a nearby locality, from which Swallow secured a part of his type specimens, good examples of both forms have been examined, but associated with them are specimens which might be either one or the other. The form to which the name *hannibalensis* has been given is smaller and rounder, while the more typical *lamellosa* is larger and more transversely subelliptical in outline. In most of the localities where *A. hannibalensis* has been found, it is associated with individuals which are good typical forms of *A. lamellosa*, and it is safe to say that the individuals usually referred to *A. hannibalensis* are nothing more than young specimens of *A. lamellosa*.

Only a few individuals have been observed in the Northview fauna, but these are all of the more typical, transversely subelliptical *A. lamellosa* form, none of them being specimens which might be referred to *A. hannibalensis*.

ATHYRIS (CLEIOTHYRIS?) sp.

Pl. IV. f. 11.

There are, among the Northview fossils, several specimens of a small shell too imperfect for certain identification, which resemble *Cleiothyris hirsuta* from the Spergen Hill fauna more closely than any other species. Some of the specimens differ from this species in being more transversely subelliptical, though others are as nearly circular as many of the Spergen Hill specimens. The nature of the surface markings of these shells cannot be satisfactorily determined, but they show numerous, rather fine, concentric lamellae. The largest specimen observed is about 15 mm. in breadth, though most of them are somewhat smaller.

It is possible that these shells may be the young of *Athyris lamellosa* which is associated with them. It also quite strongly resembles the figures of *Athyris brittsi* Miller, from the Devonian near Otterville, Missouri.

DIELASMA sp.

Pl. IV. f. 9.

A single imperfect pedicle valve of a species of *Dielasma*, has been observed in the Northview fauna. It is a shell 18 mm. in length by about 15 in breadth, regularly convex from the beak to the front margin and with no mesial sinus. It resembles some of the figures of *D. formosa*,* but it is proportionately broader than that species.

BRYOZOA.

Bryozoans apparently belonging to *Fenestella* or to some closely allied genus are not uncommon in the sandstone at Northview, but their condition of preservation is such that no identification of them can be made.

MOLLUSCA.

PELECYPODA.

CRENIPECTEN WINCHELLI (Meek)?

Pl. IV. .15.

Shell flabelliform, subequilateral, inequivalve, attaining a height of 25 mm. in the larger specimens, the extreme length about equal to or a little greater than the height. Basal margin rounded, lateral margins rounded below but straightened above: if continued to the beak they meet at an angle of about 100° or less. Hinge-line about or sometimes a little more than two-thirds the greatest length of the shell.

Left valve compressed-convex, the greatest convexity at a point about two-thirds the distance from the basal margin to the beak; the ears triangular, compressed, the anterior one somewhat smaller and more abruptly flattened from the body

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* Pal. N. Y. 8^2. *pl. 81. f. 12–26.*

of the shell, its anterior margin slightly convex or nearly straight, meeting the lateral margin of the shell below nearly at right angles; the posterior margin of the posterior ear concave, forming with the lateral margin of the shell below, a rather wide, rounded or subangular sinus. Beak erect, extending slightly beyond the hinge-line. Surface ornamented by radiating subangular costae, either nearly equal in size or with alternate smaller ones intercalated towards the margin; the spaces between the costae wider than the costae themselves. Crossing the radiating costae there are numerous, much finer and more crowded concentric striae. The ornamentation upon the ears is much less conspicuous than upon the body of the shell.

The right valve is more compressed than the left, with proportionally longer hinge-line and larger ears, and without ornamentation.

Remarks. The specimens which are referred to this species are all more or less imperfect, but they agree closely with the description and illustrations of *C. winchelli* from the Waverly sandstones of Ohio. They have also been compared directly with Ohio specimens. The one character in which the Northview specimens differ from those from Ohio, is in the almost complete absence of radiating costae upon the ears of the left valve. In the Ohio shells the ornamentation upon the ears is almost as conspicuous as upon the remainder of the shell. It is possible, therefore, that with more perfect material the Northview specimens might be shown to belong to a distinct species, though one closely allied to *C. winchelli*. The crenate hinge-line of this genus is well shown upon several of the specimens.

CRENIPECTEN LAEVIS n. sp.

Pl. IV. f. 14.

Shell flabelliform, slightly oblique, attaining a height of 29 mm. and a length of 31 mm. in the type specimen. Basal and lateral margins rounded, straightened above and if continued to the beak they meet at an angle of about 105°. Hinge-line a little more than one-half the greatest length of the shell.

The left valve, which is the only one known, compressed-convex, the greatest convexity at a point about two-thirds of the distance from the basal margin to the beak. The ears triangular, the anterior one smaller and more abruptly flattened from the body of the shell, its anterior margin nearly straight or slightly convex, meeting the straightened lateral margin of the shell below at an angle of about 150°; the posterior margin of the posterior ear concave, forming with the lateral margin of the shell below, a rather wide rounded or subangular sinus. Beaks erect, extending slightly beyond the hinge-line. Surface of the shell smooth.

Remarks. A single specimen of this species has been observed. In it the crenulated hinge-line of *Crenipecten* is clearly seen, and in general form it resembles the specimens referred to *C. winchelli*. It differs from those specimens, however, in its lack of ornamentation and in the very different form of the anterior ear.

PERNOPECTEN COOPERENSIS (Shumard).

Pl. IV. f. 22, 23.

Shell compressed-lenticular, thin, nearly equivalve, suborbicular exclusive of the ears, attaining a height of 34 mm. and a width of 32 mm. Basal margin rounded; lateral margins rounded, sometimes slightly straightened above and when continued to the beak meeting at an angle varying in different specimens from 110° to 120°. Hinge-line very short, one-third or less the greatest width of the shell. In the left valve the hinge-margins slope slightly inward from the extremities of the ears to the beak at the middle; in the right valve the hinge-margin is straight. Ears small, flat, triangular, equal or nearly so, obtusely angular at the extremities, with no trace of a byssal sinus on either side. Beaks small, compressed, not projecting above the hinge-line or showing the slightest obliquity. Superior lateral regions of the valves compressed and separated from the more convex central portion by shallow undefined impressions that diverge from the beak at an angle of from 70° to 80°, the one on the posterior side being usually the longer. The portion of the shell between these compressed regions has an elongated triangular form.

Surface of the shell ornamented with very fine, regular, crowded, concentric striae which are often scarcely recognizable without the aid of a lens. Aside from the concentric striae there are sometimes present ill-defined radiate costae which on many specimens are wholly obsolete.

Remarks. In 1855 Shumard * described *Avicula cooperensis* from the Chouteau Limestone of Cooper County, Missouri, but his figure of the type specimen, according to Meek † who examined it, along with many others from the same locality, is misleading in its representation of the strong radiating ribs and in the form of the ears. In regard to this illustration Meek says: "the figure of Shumard's species, given in the Missouri report, was drawn from a very aberrant specimen, which also had its ears partly hidden by the rock, so as to cause a misapprehension in regard to their form. The radiating costae seen on Shumard's figure, are also made *much* too strong by the engraver, even for the individual specimen there represented, while in a great majority of specimens *no traces of them whatever are to be seen.*"

In 1858 Hall ‡ indentified a species from the "Chemung Group" at Burlington, Iowa, with Shumard's *Avicula circulus*, and illustrated it in his report. This illustration is very different from Shumard's original figure § of the species to which it is referred, but agrees very well with his figure of *A. cooperensis* except for the radiating ribs which Meek says should not be there.

In 1862 White and Whitfield ‖ described without illustration, *Aviculopecten limaformis*, also from the "Chemung Group" at Burlington, Iowa.

In 1865 Winchell¶ described without illustrations the genus *Pernopecten*, with *Aviculopecten limaformis* W. & W. as the type species. The genus was characterized by the presence along the hinge-line of a central, triangular cartilage pit and

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* I and II Rep. Geol. Surv. Mo. 206. *Pl. C. f. 15.*

† Rep. Geol. Surv. Ohio 2^2: 293.

‡ Geol. Iowa 1^2: 522. *pl. VII. f. 9.*

§ I and II Rep. Geol. Surv. Mo. *pl. C. f. 14 a–b.*

‖ Proc. Bost. Soc. Nat. Hist. **8** : 295.

¶ Proc. Acad. Nat. Sci. Phil. **1865** : 125-126.

a transverse row of smaller pits or crenulations diminishing outwards. At the same time the new species *P. limatus* was described and the name *P. shumardanus* given to the *Avicula circulus* of Hall, it being pointed out that Hall's shell was not identical with Shumard's species. The characteristic cartilage pits of the genus were observed only in the type species, the other two species being placed in the genus because of their strong outward resemblance to the type.

In 1868 Meek and Worthen* identified with a query, a shell from the oolitic bed of the Kinderhook Group at Burlington Iowa, with *Pernopecten shumardanus.* They say: "In regard to the true relations of this shell to forms that have been described under several other names, we are left in so much doubt as to be considerably perplexed respecting the proper disposition to make of it. * * * , the species *Shumardianus,* of Winchell, agrees so nearly with *Avicula Cooperensis,* of Shumard, which we believe to be the same since described by Dr. White and Mr. Whitfield, under the name *Aviculopecten limaformis,* that we strongly suspect all belong to the one species *Cooperensis.*" The crenulated hinge-line of *Pernopecten* was not observed by Meek and Worthen in any of their specimens, the generic reference being made wholly upon outward resemblance.

In 1876 Meek† identified a shell from the Waverly Group at Richmond and Lodi, Ohio, with Winchell's *P. shumardanus.* It was identified with a query, however, and was referred to the genus *Entolium* instead of *Pernopecten,* because of the supposed absence of the crenulated hinge-line. Prof. Meek expresses doubt as to the true specific relations of the shell, saying, "It perhaps agrees most nearly with Prof. Winchell's description of his *Pernopecten Shumardianus.* But after seeing how these shells vary in the slight details of form and their obscure surface markings, it seems to me quite as probable that it may belong to his *P. limatus,* or rather that the latter and *P. shumardianus* may both belong to one species, also including our shell. * * * Again it certainly bears *very* close relations to *Avicula Cooperensis* Shumard,

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* Geol. Surv. Ill. **3**: 453.

† Rep. Geol. Surv. Ohio 2^2: 292. *pl. XV. f. 4a–b.*

from rocks of the same age in Missouri." As to the relation of the shell to *Aviculopecten limaformis* W. & W., the type of *Pernopecten*, Winchell, he says, "At one time I strongly suspected that *Aviculopecten limiformis* of White and Whitfield, the type of *Pernopecten*, Winchell, might also be of the same species as *Avicula Cooperensis*, Shumard; but on examining the specimens of the latter mentioned above, I was unable to discover any traces whatever, in any of them, of the crenate character of the hinge seen in the type of *Pernopecten*. * * * So we have here a remarkable case of shells presenting little or *no* constant *specific* difference, and yet differing in a character of the hinge that seems to be of generic importance."

In 1884 the type specimen of the genus and species *Pernopecten limaformis*, was illustrated by Hall * for the first time. At the same time a specimen from the Waverly Group at Newark, Ohio, called *Pernopecten Shumardanus* † was illustrated showing the characteristic crenulated hinge-line of the genus.

From the above historical sketch it will be seen that confusion has always surrounded these species of shells. So acute an observer as Prof. Meek could apparently recognize no constant characteristics of the shells from different localities which could be considered as of real specific importance. A few of the shells, however, particularly from the "Yellow Sandstone" at Burlington, Iowa, and a single specimen from Ohio, show a character of the hinge which is apparently of generic importance. Now the question is, did all of these shells possess a crenulated hinge-line when they were living, and is the condition of fossilization such in most cases that it cannot be observed, or do they really belong to two distinct genera, as seems to have been the final conclusion of Prof. Meek? Whatever may be the final decision in the matter, the specific name *cooperensis* will have to stand either for the whole or only for those without the crenulated hinge-line.

In none of the Northview specimens have the crenate hinges been observed so that they may be referred safely to the

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* Rep. N. Y. State Geol. **1882.** *pl. I. f. 1, 2.*

† Loc. cit. *pl. I. f. 3.*

species *cooperensis*. The generic reference, however, is more of a personal opinion. Personally the writer leans toward the opinion that all these shells are really a single species, but that the essential generic characters have been observed in but comparatively few individuals, therefore the Northview specimens are referred to *Pernopecten cooperensis*.

MODIOMORPHA NORTHVIEWENSIS n. sp.

Pl. IV. f. 19.

Shell small, subovate in outline, length of the type specimen 12½ mm. and the height 10 mm. Basal margin straight in the central portion, curved upward at the anterior and posterior extremities; anterior margin short, curved below into the basal margin and nearly straight above; posterior margin broadly rounded, curved from the basal to the middle of the dorsal margin. Hinge-line arcuate, oblique, extending backward to about the middle of the dorsal margin. Valves moderately convex, becoming somewhat gibbous in the umbonal region. Beaks small, pointed, placed at the extreme anterior end of the shell. Surface marked by fine subobsolete concentric striae.

Remarks. This species resembles, in a measure, the young individuals of the New York Hamilton species *Modiomorpha concentrica*, but it has the beaks placed more anteriorly and lacks the strong concentric markings of that species. The extreme anterior position of the beak seems to distinguish it from any of the remaining species of the genus.

PTYCHODESMA. — Cf. P. MINOR HALL.

Pl. IV. f. 18.

Shell small, subovate in outline, the largest specimen observed having a length of 17 mm., the height about two-thirds of the length. Basal margin regularly rounded; posterior margin broadly rounded from the basal into the dorsal margin; anterior end short, regularly rounded below the beaks. Hinge-line short and oblique. Valves regularly convex, becoming somewhat gibbous in the umbonal region. Beaks anterior, prominent, and incurved. Surface marked by fine concentric striae. Anterior muscular impression of moderate size, situated close to the anterior margin under the beak; posterior impression about equal to the anterior one in size, situated near the posterior margin at about one half the height of the shell; the two muscular impressions connected by a regularly curved, continuous pallial line.

Remarks. There seems to be no apparent reason for separating this little shell from Northview, from *Ptychodesma minor* which was originally described from the Chemung Group near Elmira, New York. Hall's* illustration of the species agrees almost exactly with the best specimen observed from Northview. Only the general form and proportions of the shells can be compared, however, and as these are usually not entirely safe criteria for the comparison of pelecypods, it is thought best to make the identification provisional. It is questionable whether the species should be referred to the genus *Ptychodesma*. The generic characters are not shown in the Northview specimens, nor, judging from Hall's description and illustration, are they clearly shown in the New York specimens of *P. minor*.

MACRODON sp.

Pl. III. f. 8.

The larger specimens about 30 mm. in length, the height about half the length; the hinge-line and basal margin subparallel. Basal margin straight or gently curving, sometimes slightly sinuous at about the middle; anterior margin broadly rounded below but nearly straight above, meeting the hinge-line at an acute angle; posterior margin rounded below, obliquely truncated above. Hinge-line straight, about equal to the greatest length of the shell. Valves gibbous in the umbonal region, with a prominent, rounded, undefined umbonal ridge extending to the posterior basal extremity, and with an undefined flattened or slightly depressed area extending from the beak to near the center of the basal margin. The posterior cardinal slope concave. Beaks prominent, elevated above the hinge-line, situated at about the anterior fourth of the total length of the shell. Surface marked by irregular concentric lines of growth and by fine radiating striae.

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* **Pal. N. Y. 5^1:** *pl. XLI. f. 27.*

Remarks. In general form this species is scarcely separable from *M. chemungensis* Hall, from the Chemung Group of New York, but it differs from that species in its surface ornamentation, there being no radiating striae upon the New York species. It also approaches *M. blairi* M. & G., from the Chouteau Limestone near Sedalia, Missouri, but seems to be distinguished from that species by its more conspicuous lines of growth and by its straighter and sometimes sinuous basal margin. With sufficiently well-preserved material it is probable that the Northview specimens would have to be considered as a new species, but for the present it seems best to leave them without a specific designation.

CARDIOPSIS RADIATA Meek and Worthen.

Pl. III. f. 5-6.

Shell obliquely subovate in outline, attaining a height of 22 mm. in the largest specimen examined, very gibbous, the two valves equal, beaks prominent, elevated above the hinge-line and closely incurved, directed anteriorly. Anterior and basal margins regularly rounded, the posterior margin obscurely subangular at its most posterior point. Hinge-line less than the greatest length of the shell, slightly arcuate. Surface of the shell covered with numerous fine, rounded, radiating costae, which are somewhat coarser upon the posterior umbonal slope. Between eighty and ninety costae may be recognized upon the most perfectly preserved specimen.

Remarks. Several genera have been established for shells of this general form, *Cardiopsis* by Meek and Worthen, in 1861, *Dexiobia* by Winchell in 1863, and *Oracardia* by Herrick in 1888. The types of all of these were found in the same general horizon, near the base of the Carboniferous System in Indiana, Iowa and Ohio. *Dexiobia* and *Oracardia* are both described as inequivalve, while in *Cardiopsis* the two valves are said to be equal. Among the Northview specimens no difference has been detected between the right and left valves, although both have been studied, and for this reason, chiefly, they are referred to the genus *Cardiopsis.* The presence or absence of hinge-teeth in these specimens cannot be determined. In the original generic description of *Cardiopsis* there are said to be two distinct anterior teeth in each valve.

C. radiata from the goniatite beds of Rockford, Indiana, is the only species of the genus which has been properly illustrated, although two others are recognized, *C. jejuna* Win., from Michigan, and *C. megambonata* Win., from Michigan and from the Yellow Sandstone at Burlington, Iowa. The last of these is possibly not distinct from *C. radiata*. The Northview specimens are lower and rounder than the figures of *C. radiata*, but the illustrations exibit some variation in this characteristic, and as the full extent of the variation cannot be determined from the literature, it is thought unwise to propose a new specific name for our shells.

CARDIOPSIS? ERECTUS n. sp.

Pl. III. f. 3-4.

Shell obliquely subovate in outline, attaining a height of 20 mm. in the largest specimen examined, moderately convex; the two valves equal, beaks prominent, highly elevated, erect, incurved but not convolute at the tips and directed forward with a concave area between the beak and the hinge-line. Anterior and posterior margins rounded, basal margin slightly flattened. Hinge-line arcuate, edentulous, less than the greatest length of the shell. Surface of the shell covered with numerous fine, simple, rounded costae, which are somewhat coarser upon the posterior umbonal slope. Between sixty and seventy costae may be counted upon the type specimen. Besides the radiating costae there are a few concentric wrinkles, irregular in position and in intensity.

Remarks. This species is similar to the last, but may be distinguished by its less gibbosity, its erect beaks, and its concentric wrinkles. The absence of hinge-teeth would seem to exclude the species from *Cardiopsis*, and possibly it should be placed in the genus *Dexiobia* which is said to be "edentulous (?)" in the original description, leaving this characteristic somewhat in doubt. The equal valves of the shell, however, are against placing it in *Dexiobia* and it is therefore referred provisionally to *Cardiopsis*, leaving the final decision until a time when all the species of these genera from various localities can be studied together and adequate comparisons made.

PALAEONEILO CONSTRICTA (Conrad)?

Pl. IV. f. 20.

Shell subovate in general outline, sub-nasute behind, from 15 to 23 mm. in length, the height about two-thirds of the length, with the highest point in front of the middle. Basal margin regularly rounded from the middle to the anterior extremity and straightened or slightly constricted towards the posterior extremity; posterior margin narrowly rounded; anterior margin more broadly rounded. Hinge-line arcuate, declining more abruptly at the front, marked by numerous crenulations. Valves convex below the beaks, somewhat compressed posteriorly. Beaks at about the anterior third, prominent, rising above the hinge-line. Umbonal ridge undefined; an ill-defined depression or broad sulcus sometimes present, extending from just behind the beak to the straightened or sinuate posterior basal margin. Surface marked by fine, regular, thread-like concentric striae which are often obsolete or nearly obsolete upon the posterior portion of the shell.

Remarks. This species is represented by a considerable number of specimens in the Northview collection, and they seem to be closely allied or identical with the New York Hamilton species *Palaeoneilo constricta.* The crenulated hinge-line of the genus is well shown in several specimens, and in form, proportions and surface markings the specimens agree exactly with the illustrations and specimens of the New York shell. *P. bedfordensis* Meek, from the Bedford shale at Bedford, Ohio, is also a closely allied species, and should possibly be considered as identical with *P. constricta.* It seems, however, to be relatively a shorter shell than *P. constricta.*

PALAEONEILO TRUNCATA Hall.

Pl. IV. f. 21.

Shell attaining a length of 30 mm. or more in the largest specimens, length about twice the height. Valves strongly convex, the beaks moderately prominent, rising above the hinge line and situated about one-fourth the length of the shell from the anterior extremity. Basal margin nearly straight; posterior margin backwardly truncate or slightly sinuate below, rounded above into the cardinal margin; anterior margin rather sharply rounded below, becoming straightened above and meeting the cardinal margin in a rounded obtuse angle. Hinge-line straight posteriorly, turned downward in front, the straight portion sub-parallel with the basal margin. A prominent rounded umbonal ridge extends from the beak to the posterior extremity of the basal margin and another similar but less conspicuous ridge extends from the beak to the most posterior extension of the shell. The area between these two ridges is depressed, forming a conspicuous sinus. The whole surface of the shell covered with fine angular concentric costae about ½ mm. apart upon the outer position of the shell, but becoming much more closely crowded towards the beak.

Remarks. In the original specimens of this species from the Waverly Group of Ohio, the anterior margin is quite regularly rounded, while in the Northview specimens it is rather sharply rounded below and straightened above. In all other respects the agreement is close. *P. marshallensis* Win. is a closely allied species and may possibly be identical with *P. truncata.*

SCHIZODUS AEQUALIS Hall.

Pl. III. f. 10.

Height of shell about 35 mm. in the larger examples, the length a little greater than the height. Basal margin regularly curved; the anterior margin broadly rounded below, becoming straighter towards the cardinal line; posterior margin truncated somewhat vertically. Hinge-line short. Valves regularly convex, the greatest depth about 10 mm., at a point somewhat above the middle point of the shell. Beaks subcentral, elevated above the hinge-line. The umbonal ridge obtusely subangular, extending from the beak to the posterior basal extremity. The posterior cardinal slope concave. Surface marked by fine concentric striae which are more conspicuous towards the margin of the shell.

Remarks. None of the Northview specimens of this species are entirely complete. So far as they are preserved, however, they agree closely with this species, which was originally described from the Waverly Sandstone at Granville, Ohio.

ELYMELLA MISSOURIENSIS Miller and Gurley.

Pl. III. f. 9.

Shell about 23 mm. in length, subelliptical in outline, narrower in front, the height one-half the length. Anterior end narrowly rounded, posterior end narrowly rounded below and arcuate above and forming an obtuse angle with the hinge-line, basal margin arcuate. Hinge-line straight, about two-thirds the extreme length of the shell, sloping to the anterior end. Hinge-teeth unknown. Valves convex, gibbous in the umbonal region; beaks prominent, placed near the anterior end and incurved over the hinge-line. Posterior cardinal slope concave, the umbonal ridge subangular at first but gradually merging into the general convexity of the shell. Surface ornamented with regular concentric striae about 1 mm. apart upon the posterior umbonal slope, but becoming much closer towards the anterior end of the shell.

Remarks. This species was originally described from the Chouteau limestone near Sedalia, Missouri. The Northview specimen is a little more elongate and has a more pointed posterior extremity with an obtusely angular junction between the posterior and dorsal margins, than the illustration of the type specimen of the species. This difference, however, is not considered sufficient to establish a distinct species.

PROMACRUS WEBSTERENSIS n. sp.

Pl. II. f. 2. Pl. III. f. 1.

Shell large, rather compressed, 15 cm. or more in length, the height a little more than one-fourth the length. Basal margin nearly straight from end to end; anterior margin narrowly rounded at the extremity; posterior margin sharply rounded below, obliquely truncated above, meeting the dorsal margin in a rounded, obtuse angle; dorsal margin straight posteriorly and subparallel with the basal margin, also nearly straight anterior to the beak but sloping downward to the narrowly rounded anterior end. Beaks broadly obtuse, situated a little anterior to the middle of the valves. A rounded umbonal ridge extends from the beak to the posterior basal extremity; anterior to this ridge the shell is moderately convex from the dorsal to the basal margins, becoming flattened anteriorly; posterior to it the shell is slightly concave, becoming compressed towards the margins. Just below the dorsal margin and subparallel with it, posterior to the beak, there is a long stright hinge-tooth, represented in the specimens by a groove. The whole surface of the shell is covered with more or less discontinuous and irregular concentric ridges, with the posterior slope smoother than the remainder of the shell.

Remarks. The species is most nearly allied to *P. missouriensis* Swall., described from the Kinderhook Group of Pike County, Missouri, and in order that a comparison between the two species may be made, a copy of Meeks* illustration of the specimen of that species is introduced on plate II. The Northview species differs from *P. missouriensis* in its more rounded umbonal ridge, in its slightly arcuate posterior margin which meets the basal margin with a less acute angle and in the larger angle between the umbonal ridge and the basal margin.

Fragments of this shell are not at all uncommon in the Vermicular Sandstone at Northview, but only a small number of specimens approaching perfection have been found.

Promacrus cuneatus Hall.

Pl. III. f. 2.

Shell below medium size for this genus, attaining a length of about 85 mm., a little more than three times as long as high, compressed anteriorly but more convex posteriorly, the beaks situated at a point posterior to the middle. Basal margin nearly straight, anterior margin narrowly rounded at the extremity; posterior margin straight, oblique, meeting the basal margin at an acute angle of about 60°; dorsal margin with a long, nearly straight slope in front of the beak, straight and slightly sloping back of the beak. The posterior umbonal ridge sharply carinate from the beak to the posterior basal angle, the posterior slope short, concave. Surface

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* Am. Jour. Conch. 7. *pl. I. f. 1.* (1871).

marked by sharply defined concentric ridges, with less distinct radiating striae which become nodose at their intersections with the concentric ridges. The posterior slope from the umbonal ridge smooth, except for rather faint lines of growth.

Remarks. The specimen upon which this species was founded by Hall is a very imperfect one from the "Yellow Sandstone" of Burlington, Iowa, in which only that portion of the shell anterior to the beak is preserved. The illustration of the type specimen shows the shell with a somewhat more sharply pointed anterior end than is possessed by any of the Northview specimens, but the surface markings in the two are peculiar and are apparently identical, so that it is believed that they belong to the same species. The species may be easily distinguished from the last by its smaller size, its more posteriorly placed beaks, and by its peculiar surface markings. The surface markings and the size will also distinguish it from any of the other species of the genus.

Fragments of this species are not uncommon at Northview, but only one specimen approaching perfection has been found.

SANGUINOLITES WEBSTERENSIS n. sp.

Pl. III. f. 7.

Shell 75 mm. in length, more than twice as long as broad, subelliptical in outline, narrower in front. Anterior end narrowly rounded; posterior end broadly and quite regularly rounded; basal margin nearly straight posteriorly but rounded upward at the anterior extremity. Hinge-line more that two-thirds the length of the shell, straight posterior to the beak and sloping forward anteriorly from the beak. Valves moderately convex, the beaks situated near the anterior end. An obscurely angular, inconspicuous, umbonal ridge extends from the beak to the posterior basal margin of the shell, and upon the cardinal slope above this umbonal ridge three additional inconspicuous ridges may be detected. The surface of the shell ornamented with irregular concentric lines of growth.

Remarks. This species closely resembles a shell from the Waverly Group of Licking County, Ohio, which was identified by Herrick[*] with *Sanguinolites nobilis* De Kon. On comparison with De Koninck's illustration of the Belgian shell, however, there seems to be sufficient difference to exclude the Northview specimens from that species, and it seems to be a necessity to establish a new species for its reception. The Ohio shell described by Herrick should doubtless be included in this new species.

EDMONDIA BURLINGTONENSIS W. & W.

Pl. IV. f. 16.

Shell 30 to 35 mm. in length, the height about two-thirds the length, broadly subelliptical in outline. Anterior and posterior margins broadly and subequally rounded; basal margin nearly straight in the middle, curving into both extremities. Hinge-line straight, subparallel with the basal margin, about one-half as long as the shell. The anterior and posterior portions of the cardinal margin gently curving into the anterior and posterior margins of the shell. Valves moderately convex, slightly flattened in the umbonal region. Beaks prominent and incurved, situated at about the anterior fourth of the total length of the shell. Surface marked by fine concentric striae which are sometimes more or less fasciculate and produce undulations which are more conspicuous on the posterior half of the shell.

Remarks. This is not an uncommon shell in the Northview fauna. It differs slightly from Hall's illustrations of the species, which were drawn from typical examples from the "Yellow Sandstone" at Burlington, Iowa, in its less prominent beaks, but this difference is not believed to be of specific importance.

EDMONDIA MISSOURIENSIS n. sp.

Pl. IV. f. 17.

Shell from 20 to 24 mm. in length, the height about two-thirds of the length; subelliptical in general outline. Basal margin rounded from the most anterior to the most posterior points of the shell; anterior margin rather broadly rounded

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[*] Bull. Den. Univ. **3**: 71. *pl. X. f. 5.*— Also Geol. Surv. Ohio **7.** *pl. XIII. f. 20.*

up to the anterior end of the hinge-line; posterior margin more narrowly rounded at its most posterior extension and nearly straight above, where it slopes up to the hinge-line. Hinge-line slightly arcuate, more than one-half the total length of the shell. Valves regularly convex, the greatest depth being about one-fourth of the height. Beaks rather small and incurved, situated at about the anterior fourth of the total length of the shell. Surface marked by more or less inconspicuous concentric striae.

Remarks. This shell may be easily distinguished from the last by its smaller size, by its more pointed posterior extremity, and generally by its smoother surface.

GASTEROPODA.

Bellerophontidae.

No less than sixteen species of this family have been described from Iowa, Ohio, Michigan, etc., from strata of about the age of the Vermicular Sandstone, but of these only six have been illustrated, and in most cases even these have not been illustrated from typical specimens. Under these circumstances it is exceedingly difficult to identify with any certainty the species of the genera included in this family. American writers have almost universally included all the *Bellerophontidae* in the single genus *Bellerophon*, but several very distinct groups of shells have obviously been included in this genus. In his monograph of the Carboniferous fossils of Belgium, De Koninck* has recognized seven genera among the carboniferous *Bellerophontidae* of Belgium, and his generic divisions will be used in this paper.

Among the Northview fossils, at least four species, belonging to as many genera, of *Bellerophontidae* have been collected. All the specimens are imperfect to a greater or less degree so that certain identification would be difficult even were the known species well illustrated, but under the circumstances it is impossible to be sure whether some of the Northview specimens belong to already described species or whether

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* Faun. du Calc. Carb. de la Belg. pt. 4. Gasteropods.

they are new species; therefore the specimens will simply be referred to their proper genera, and identified specifically as well as possible, with such descriptions and illustrations as can be made, without attempting to found any new species.

TROPIDODISCUS CYRTOLITES (Hall).

Pl. V. f. 8-9.

Shell sublenticular, umbilicate, the periphery angular. The sides of the outer whorl converging with a slightly convex outline from near the umbilicus nearly to the prominent angular periphery where the shell is slightly compressed; rather abruptly curved inward to the umbilicus. The aperture subcordate, the margin with a broad and deep but not sharply defined sinus at the dorsal angle. Surface covered with very fine but conspicuous costae parallel with the margin of the aperture, and by much less distinct revolving lines, which together give to the shell under a lens, a very beautiful cancellated appearance.

Remarks. This species belongs to a group of the *Bellerophontidae* with *B. curvilineatus* Conrad, as the type, for which Meek * proposed the name *Tropidiscus*, but a little later changed it to *Tropidodiscus*.† De Koninck ‡ pointed out that the name *Tropidiscus* was already preoccupied in 1850 by Stein for a genus of fresh water snails, and proposed to substitute *Tropidocyclus* instead of using Meek's second name *Tropidodiscus*. Since there seems to be nothing against the name *Tropidodiscus* it is adopted here instead of DeKoninck's much later name *Tropidocyclus*.

The species is represented by several specimens from Northview, all of which are fragmentary, although one of them shows the margin of the aperture in great perfection. The species was originally described from internal casts from the "goniatite beds" at Rockford, Indiana, and in the typical specimens the delicate surface markings seen in the Northview specimens were not preserved. The species has been found, however, in some of the Waverly beds of Ohio and

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* Proc. Chicago Acad. Sci. 1: 9. (March, 1866).

† Geol. Surv. Ill. 2: 160. (1866).

‡ Faun. du Calc. Carb. de la Belg. pt. 4: 160. (1883).

has been described as having surface markings like those of the Northview specimens, so that there can be little doubt as to the identity of the species.

EUPHEMUS ? sp.

Pl. V. f. 10–11.

A single imperfect specimen of this little species has been found in the Northview fauna, about one half of the outer whorl being preserved. It is 8½ mm. in diameter and expands gradually towards the aperture, the greatest thickness of the shell being 5 mm. The shell is umbilicate, the margin of the umbilicus being angular. The outer portion of the shell from the margin of the umbilicus on one side to the margin of the opposite umbilicus is subsemicircular in outline, becoming slightly angular towards the aperture; no dorsal band marking the periphery. The surface is marked by twelve, equal, revolving costae which extend to the margin of the aperture, the spaces between being about equal in width to the costae themselves. The costae apparently increase in number as the shell increases in size, by the addition of new ones, at the margin of the umbilicus.

It is possible that this species should not be placed in the genus *Euphemus* because of the presence of the umbilicus, and because the revolving costae extend to the aperture of the shell. It agrees more closely with this genus, however, than with any other, and is therefore provisionally placed in it.

BUCANIA ? sp.

Pl. V. f. 12.

Shell rather abruptly expanding at the aperture, the cross-section regularly curved on the outside, with a narrow, slightly elevated peripheral band. Surface of the shell marked by fine thread-like revolving costae about one mm. apart, with about four very much finer ones in each intermediate space, and also by fine transverse lines of growth which curve backward very slightly as they approach the peripheral band. Aperture wider than deep with a dorsal notch apparently of moderate depth.

Remarks. Only two specimens of this shell have been observed, and one of these differs from the above description in the character of the revolving costae, which are all nearly equal in size. Both specimens are imperfect and it is possible that they should be referred to some one of the species of *Bellerophon* already described from about this horizon, but which has never been illustrated.

BELLEROPHON sp.

This is a smooth, subglobular species with a narrow, inconspicuous peripheral band, and has much the aspect of *B. sublaevis* of the St. Louis Limestone fauna. It is represented by several imperfect and distorted specimens none of which are sufficiently well preserved to be described in detail or illustrated.

MOURLONIA NORTHVIEWENSIS n. sp.

Pl. V. f. 13.

Shell about 25 mm. in diameter, turbinate, umbilicate, whorls angular on the periphery, sutures deeply impressed, total number of whorls unknown. The peripheral band narrow, flat, and slightly elevated. Slopes of the shell, both above and below the peripheral band, moderately convex and in the last whorl it rounds over quite abruptly below into the umbilicus. The whole surface covered with fine, subequal, revolving lines, and by lines of growth which on the upper side of the whorls are about equal in size to the revolving lines, but below the peripheral band they are less distinct. The lines of growth below and those above meet at the peripheral band in an angle of about 120°. The aperture is notched, but without a peripheral slit.

Remarks. This species is one of the *Pleurotomaridae* and apparently possesses all the essential characters of the genus *Mourlonia*.

PLEUROTOMARIA ? sp.

This species is represented by a single imperfect and much distorted specimen, though enough of it is preserved to show it to be distinct. The peripheral band is angular and the fine, regular lines of growth above and below it meet upon it in an obtuse angle. On the upper slope of the whorl, about half way between the peripheral band and the suture, there is an angular, revolving carina, and on both sides of it, between it and the peripheral band on the one side and the suture on the other, the shell is concave. A short distance below the peripheral band there is a prominent, flattened, revolving band. Between this band and the periphery the shell is concave, but below it is convex, rounding over gradually into the umbilicus. The number of whorls cannot be determined as only a portion of the outer one is preserved.

This shell does not properly belong to the genus *Pleurotomaria*, but it is one of the *Pleurotomaridae* and is placed here provisionally until more perfect specimens can be had.

PLATYSCHISMA MISSOURIENSIS n. sp.

Pl. V. f. 1–4.

Shell composed of six whorls, umbilicate, with a low spire, the diameter 44 mm., and the total height 30 mm. Each whorl of the spire is about, or a little more than one-half covered by the next outer one, the exposed portion being flattened above and rounded laterally down to the well marked suture. The outer whorl is somewhat depressed so that the cross section is subelliptical in outline, but towards the aperture it is slightly expanded, the aperture itself being subcircular in outline, with a height of 22 mm. and a width of about 23 mm. The margin of the aperture is broadly sinuate near the columella, it then projects forward with a rounded outline to a point a little below the middle of the outside of the whorl where it again becomes slightly sinuate. Above this it again projects slightly forward for a short distance and then curves backward somewhat abruptly to form the rather narrow and deep sinus which is situated at the upper part of the outer side of the whorl, from this sinus the margin continues in a nearly regular convex curve to the point of junction with the second whorl. If straightened out the margin of the aperture would have the form of the accompanying curve (*pl. V. f. 4*), the upper end of the line being at the suture between the outer whorl and the next inner one, and the lower being at the columella.

The surface of the specimen is for the most part smooth except the last third of the outer whorl which is marked by rather fine irregular lines of growth.

Remarks. This shell has the general aspect of a *Straparollus*, and unless the aperture or the lines of growth are observed, it is impossible to identify the genus with certainty. The genus has not heretofore been recognized in America although several species have been described from the European formations which are equivalent to our Mississippian Series.

A single complete individual has been observed in the Northview fauna, but numerous fragments occur which are believed to belong to the same species.

STRAPAROLLUS ? sp.

Pl. V. f. 14.

A single specimen of a small lenticular shell in the sandstone at Northview is probably a member of this genus, but it is too imperfectly preserved to permit certain identification.

PHANEROTINUS PARADOXUS Winchell.

Pl. V. f. 6.

This shell is a smooth, gradually expanding, cylindrical tube, subcircular in cross section, loosely coiled in a plane, the successive whorls not in contact. A single imperfect specimen has been found in the Northview fauna.

CAPULUS sp.

Pl. V. f. 15.

A single small specimen of this genus about 9 mm. in diameter has been observed. It resembles *C. haliotoides* in general form but is too imperfect for certain identification.

PORCELLIA. — Cf. P. RECTINODA Win.

Pl. V. f. 7.

Shell small; increasing gradually in size, the increase being about 1 mm. in a distance of 17 mm. upon the outside of the whorl; subcircular in cross section, diameter of the largest specimen 9 mm. Nodes elongate becoming more or less attenuate interiorly, slightly oblique, most prominent at a point from $\frac{2}{5}$ to $\frac{1}{2}$ the distance from the periphery to the inside of the whorl, the distance from center to center equal to about $\frac{2}{3}$ the diameter of the cross section of the shell at that point. Surface marked by extremely faint revolving lines and by still fainter transverse lines; neither of these are conspicuous, however, and ordinarily the specimens appear to be smooth.

Remarks. This species has been observed only in the form of fragments, not a single specimen exhibiting a complete whorl having yet been found. In all cases these fragments are only one-half of the shell, as if the shell were split in the plane of its coil, a manner of occurrence that would seem to indicate that the shell was so constituted as to separate with ease along the peripheral band.

Four species of this genus have been recorded from the Kinderhook of Iowa and Illinois, but three of these have never been illustrated. The Northview shell differs from *P. nodosa* Hall, in its more gradual increase in size and in its more frequent nodes. It seems to approach nearest to *P. rectinoda* Win., from the "Yellow Sandstone" at Burlington, Iowa, although this species was but very briefly described and was never illustrated. The Northview shell differs from it in being larger, and perhaps in other characteristics which cannot be determined certainly from the published description. From the other two described species the Northview shell differs to such an extent that no comparison need be made.

LOXONEMA sp.

Pl. V. f. 5.

This species is represented by several more or less imperfect, elongate conical shells, with smooth, convex whorls and moderately impressed sutures. It evidently belongs to the smooth shelled division of the genus as described by De Koninck.* The specimens are not perfectly enough preserved to allow specific identification or description, but in their general form they resemble the Belgian species *L. lefebvrei* Léveillé.†

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* Faun. du Calc. Carb. de la Belg. pt. 3.

† Loc. cit. *pl. V. f. 7.*

CEPHALOPODA.

ORTHOCERAS CHEMUNGENSE Swallow.

Pl. V. f. 16.

"Shell small, tapering moderately; transverse section elliptical; septa very concave; distant nearly half the shorter diameter; siphuncle small, central."

"Longest diameter, .64; shorter diameter, .51; distance of septa, .24; diameter of siphuncle, .06."

Remarks. This species was originally described from the Lithographic Limestone of Marion and Pike Counties, Missouri, and the original description is copied above in full. Since the sutures are rarely recognizable in the Northview specimens it is probable that most of them are fragments of the living-chamber, which was apparently rather long. The specimens agree closely with Swallow's description. The proportions of long diameter, short diameter and distance of septa in the best preserved specimen are 65–52½–26, as against 64–51–24 as given by Swallow. The largest shell among the Northview fragments has a long diameter of 24 mm., which is perhaps greater than any of Swallow's specimens although he makes no statement in the description further than that the shell is small. Upon the better preserved specimens very fine lines of growth may be recognized, though in general the specimens are smooth, and in one fragment the shell shows a moderate constriction so it is possible that the shell was somewhat constricted near the aperture. In no specimen has the position of the siphuncle been observed.

TRIBOLOCERAS DIGONUM (M. & W.)?

Pl. V. f. 17-18.

This species is only known from fragmentary specimens, all of which are apparently portions of casts of the living-chamber, as in no case have the sutures been observed. The form and ornamentation of the shell, however, show that it is a member of this genus, and that it approaches very close to or is identical with *T. digonum*.

Some of the Northview specimens are broader across the flattened ventral side of the whorl than those figured by Meek and Worthen. The entire surface is longitudinally fluted by angular ridges from 1 to 2 mm. apart, and the outer flattened portion is in addition covered by numerous fine longitudinal striae. In the description of *T. digonum* only one style of longitudinal markings is mentioned; whether this corresponds to the flutings of the Northview specimens or to the fine longitudinal striae is difficult to determine from the description, but judging from the illustration of the species, it is the coarser marking. If the fine longitudinal lines are not present upon the original *T. digonum*, then the Northview specimens doubtless represent a distinct species. The shell is also marked by transverse striae of growth, nearly as fine but less regular than the fine longitudinal striae. These lines of growth are more conspicuous in the central portion of the flattened ventral side of the shell, and bend backward from the margins to the center of the ventral side so that the aperture of the shell must have been deeply and broadly sinuate. At the points where the transverse striae cross the longitudinal flutings of the shell there are slight prominences which are more conspicuous upon the lateral portions of the shell.

ARTHROPODA.

TRILOBITA.

Proetus sp.

Two fragments of trilobites occur among the Northview fossils. One is the glabella of a small species of *Proetus*, and the other is a nearly complete pygidium which may belong to the same genus or to *Phillipsia*.

PLANTAE. ?

Spirophyton sp.

Pl. VI. f. 2.

There are present everywhere upon the weathered surfaces of the Vermicular sandstone, flattened impressions marked by moderately fine crescentic ridges which become more or less confluent at the margins. These impressions seem to agree in all essential respects with the similar ones called *Spirophyton* which were described by Hall * from the Devonian strata of New York and interpreted by him as fucoid impressions. Recently some similar forms have been described from the Devonian strata of Iowa and Illinois by Udden,† with the suggestion that possibly they may be the coprolites of some mud-burrowing animal with habits similar to some of the living Holothuroidea. Whatever may have been the source of these impressions, whether they be fucoids or coprolites, they are all apparently similar and may be referred to by the generic name *Spirophyton*, although it would seem that they scarcely present characters sufficient for specific distinctions.

CORRELATION.

A critical examination of the Northview fauna, gives us the following twenty-four species which, with a reasonable degree of certainty, are identified with species known from other localities.

Orthothetes chemungensis.
Schizophoria swallovi.
Rhipidomella burlingtonensis.
Chonetes illinoisensis.
Chonetes cf. *tumidus.*
Productella concentrica.
Spirifer marionensis.
Syringothyris carteri.
Athyris lamellosa.
Crenipecten winchelli.
Pernopecten cooperensis.
Cardiopsis radiata.
Palaeoneilo constricta?
Palaeoneilo truncata.
Schizodus aequalis.
Elymella missouriensis.
Promacrus cuneatus.
Sanguinolites websterensis.
Edmondia burlingtonensis.
Tropidodiscus cyrtolites.
Phanerotinus paradoxus.
Porcellia cf. *rectinoda.*
Orthoceras chemungensis.
Tribloceras digonum.

Of the species in this list fifteen, or 62½%, are known to occur in the Kinderhook faunas at various localities in Missouri, Illinois, and Iowa, as seen in the following table. Ten

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* N. Y. State Cab. Nat. Hist. **16**, appendix D. 76–83.

† Jour. Geol. 6^2 : 193. (1898).

of these species are present in Yellow Sandstone strata at Burlington, Iowa.

Names of Species.	Yellow S. S. Burlington, Ia.	Marion and Pike Cos., Mo.	Wassonville, Ia.	Jersey Co., Ill.	Cooper Co., Mo.	Moniteau Co., Mo.	Callaway Co., Mo.	Sedalia, Mo.
Rhipidomella burlingtonensis	x	x	....	....	....	....	....	....
Chonetes illinoisensis	x	....	x	....	....	....	....	....
Productella concentrica	x	....	....	....	....	....	....	....
Spirifer marionensis	....	x	....	....	x	x	....	....
Syringothyris carteri	x	x	....	....	....	....	....	....
Pernopecten cooperensis	x	x	....	....	x	....	....	....
Cardiopsis radiata	....	....	....	x	....	....	....	....
Elymella missouriensis	....	....	....	....	....	....	....	x
Promacrus cuneatus	x	....	....	....	....	....	....	....
Edmondia burlingtonensis	x	....	....	....	....	....	....	....
Tropidodiscus cyrtolites	x	....	....	....	....	....	....	....
Phanerotinus paradoxus	x	....	....	....	....	....	....	....
Porcellia cf. *rectinoda*	x	....	....	....	....	....	....	....
Orthoceras chemungensis	....	x	....	....	....	....	....	....
Tribloceras digonum	....	....	....	x	....	....	x	....

Thirteen species of the twenty-four, or 54%, occur in the faunas of three of the divisions of the Waverly series in Ohio, and of these thirteen, six species have not hitherto been recorded from the Kinderhook of the Mississippi Valley. The stratigraphic position of these thirteen species in Ohio is as follows: —

I. Upper part of Berea Shale.
Chonetes cf. *tumidus.*
Productella concentrica.
Spirifer marionensis.
Pernopecten cooperensis.
II. Upper 50 feet of Cuyahoga Shale.
Athyris lamellosa.
Palaeoneilo truncata.
Edmondia burlingtonensis.
Tropidodiscus cyrtolites.

III. Freestone of central Ohio. Base of Logan Group.
Chonetes illinoisensis.
Syringothyris carteri.
Crenipecten winchelli.
Schizodus aequalis.
Sanguinolites websterensis.

In his correlation of the Ohio formations in the Waverly Series, Herrick* referred the third or highest of these divisions to the Kinderhook of the Mississippi valley, the two lower ones, I. and II., being considered as equivalent to a part of the Chemung further east. In the Northview fauna, species from all three of these divisions are associated, there being a larger number of species from the two lower ones than from the higher one, which would seem to indicate that the Kinderhook division of the Waverly in Ohio, should include more than was allotted to it by Herrick.

The following five species in the Northview fauna are also present in the goniatite beds at Rockford, Indiana: —

Chonetes illinoisensis.
Productella concentrica.
Cardiopsis radiata.
Tropidodiscus cyrtolites.
Tribloceras digonum.

There remain three species in the list of twenty-four, which have not been mentioned. These are *Schizophoria swallovi*, *Orthothetes chemungensis*, and *Palaeoneilo constricta?* The first of these is typically a member of the Osage fauna, but the Northview specimens are somewhat intermediate in form between the typical species as it occurs in the Osage, and *S. impressa* of the Chemung fauna in New York. The last two species are Devonian, and normally are members of the Hamilton and Chemung faunas in New York. These two species having a Devonian aspect, however, are not alone in the Northview fauna. The presence of a species of the genus *Modiomorpha* which has so great a development in the New

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* Geol. Surv. Ohio **7**: 495–515.

York Hamilton and Chemung faunas, and the abundance of the two species of *Palaeoneilo* may be considered as Devonian elements in the fauna. It is not surprising, however, to find such an element in a fauna contained in strata lying almost at the base of the Carboniferous.

Aside from the twenty-four species already considered, the following eight species described here for the first time, deserve consideration: —

Ambocoelia parva.	*Promacrus websterensis.*
Crenipecten laevis.	*Edmondia missouriensis.*
Modiomorpha northviewensis.	*Mourlonia northviewensis.*
Cardiopsis erecta.	*Platyschisma missouriensis.*

The genera are mostly those occurring in the Kinderhook faunas elsewhere. *Ambocoelia parva* is allied to *A. minuta* of the Kinderhook, and also to the Devonian species *A. umbonata*. *Promacrus websterensis* is most closely allied to *P. missouriensis* from the Kinderhook in Pike County, Missouri, but it is also less closely allied to *P. andrewsi* which was described from the Waverly group in Ohio. The genus *Platyschisma* is here recognized for the first time in America. In Europe it is represented by several species in the Carboniferous limestone. To the genus *Mourlonia*, several species, both Devonian and Carboniferous, usually placed in *Pleurotomaria*, will probably have to be added.

EXPLANATION OF ILLUSTRATIONS.

PLATES II.-VI.

(ALL OF THE FIGURES ARE OF NATURAL SIZE.)

Plate II. — 1, *Promacrus missouriensis* Swall. A copy of Meek's figure of this species, introduced here for comparison with *P. websterensis*. — 2, *Promacrus websterensis* n. sp. Lateral view of one of the type specimens.

Plate III. — 1, *Promacrus websterensis* n. sp. One of the type specimens showing the long groove near the dorsal margin posterior to the beak. — 2, *Promacrus cuneatus* Hall. Lateral view of a nearly perfect left valve. — 3-4, *Cardiopsis? erectus* n. sp. View of a perfect right valve and a profile of the same in outline. — 5-6, *Cardiopsis radiata* M. & W. View of a perfect right valve and a profile of the same in outline. — 7, *Sanguinolites websterensis* n. sp. Lateral view of a nearly perfect right valve. — 8, *Macrodon* sp. Lateral view of a nearly perfect right valve. — 9, *Elymella missouriensis*

M. & G. View of a perfect left valve. — 10, *Schizodus aequalis* Hall. View of an imperfect left valve.

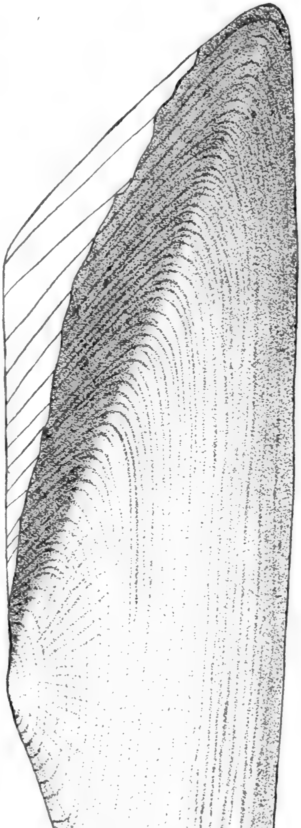
Plate IV. — 1–4, *Ambocoelia parva* n. sp. Four views of two specimens, both pedicle valves. — 5–6, *Syringothyris carteri* Hall. Views of the cardinal area of a large but imperfect specimen, and a small but very perfect brachial valve. — 7, *Schizophoria swallovi* Hall. View of an internal cast of a pedicle valve, showing the muscular impressions. — 8, *Athyris lamellosa* Léveillé. View of an internal cast of a pedicle valve. — 9, *Dielasma* sp. View of an imperfect pedicle valve. — 10, *Chonetes illinoisensis* Worthen. View of an imperfect pedicle valve. — 11, *Athyris* (*Cleiothyris?*) sp. View of a nearly perfect pedicle valve. — 12, *Spirifer marionensis* Shum. View of a nearly perfect brachial valve. — 13, *Rhipidomella burlingtonensis* H. View of a nearly perfect pedicle valve. — 14, *Crenipecten laevis* n. sp. View of the type specimen — 15, *Crenipecten winchelli* Meek. Lateral view of a somewhat imperfect specimen. — 16, *Edmondia burlingtonensis* W. & W. View of a nearly perfect right valve. — 17, *Edmondia missouriensis* n. sp. View of the type specimen. — 18, *Ptychodesma.* cf. *minor* Hall. View of a nearly perfect right valve. — 19, *Modiomorpha northviewensis* n. sp. View of the type specimen. — 20, *Palaeoneilo constricta* Con. View of a left valve in which the umbonal region is imperfect, but in which the impressions of the cardinal teeth may be seen. — 21, *Palaeoneilo truncata* Hall. — View of a nearly perfect specimen preserving both valves. The impressions of the cardinal teeth may be seen anterior to the beaks. — 22, 23, *Pernopecten cooperensis* Shumard. Lateral views of two different specimens.

Plate V. — 1–4, *Platyschisma missouriensis* n. sp. Three views of the type specimen with a tracing of the form of the aperture. — 5, *Loxonema* sp. View of a somewhat imperfect specimen. — 6, *Phanerotinus paradoxus* Win. Outline of an imperfectly preserved specimen. — 7, *Porcellia.* cf. *rectinoda* Win. View of one of the best preserved fragments from Northview. — 8, 9, *Tropidodiscus cyrtolites* Hall. Lateral and dorsal views of a specimen in which the margin of the aperture is perfectly preserved. — 10, 11, *Euphemus?* sp. Lateral and dorsal views of the only specimen observed. — 12, *Bucania?* sp. View of an imperfect specimen. — 13, *Mourlonia northviewensis* n. sp. Lateral view of the type specimen. — 14, *Straparollus* sp. — 15, *Capulus* sp. — 16, *Orthoceras chemungense* Swallow. — 17, *Tribloceras digonum* M. & W.? View of the outer side of an imperfect fragment and an outline of the cross section of a smaller individual.

Plate VI. — 1, *Scalarituba missouriensis* n. gen. and n. sp. A fragment of the weathered surface of the sandstone showing the worm burrows. — 2, *Spirophyton* sp.

Issued April 22, 1899.

PLATE II.



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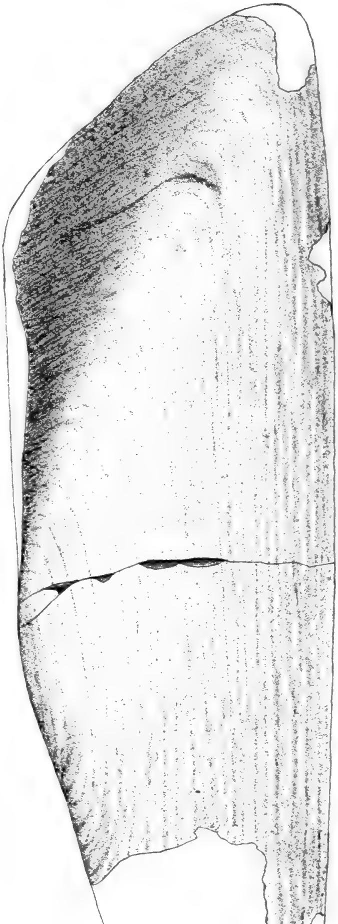
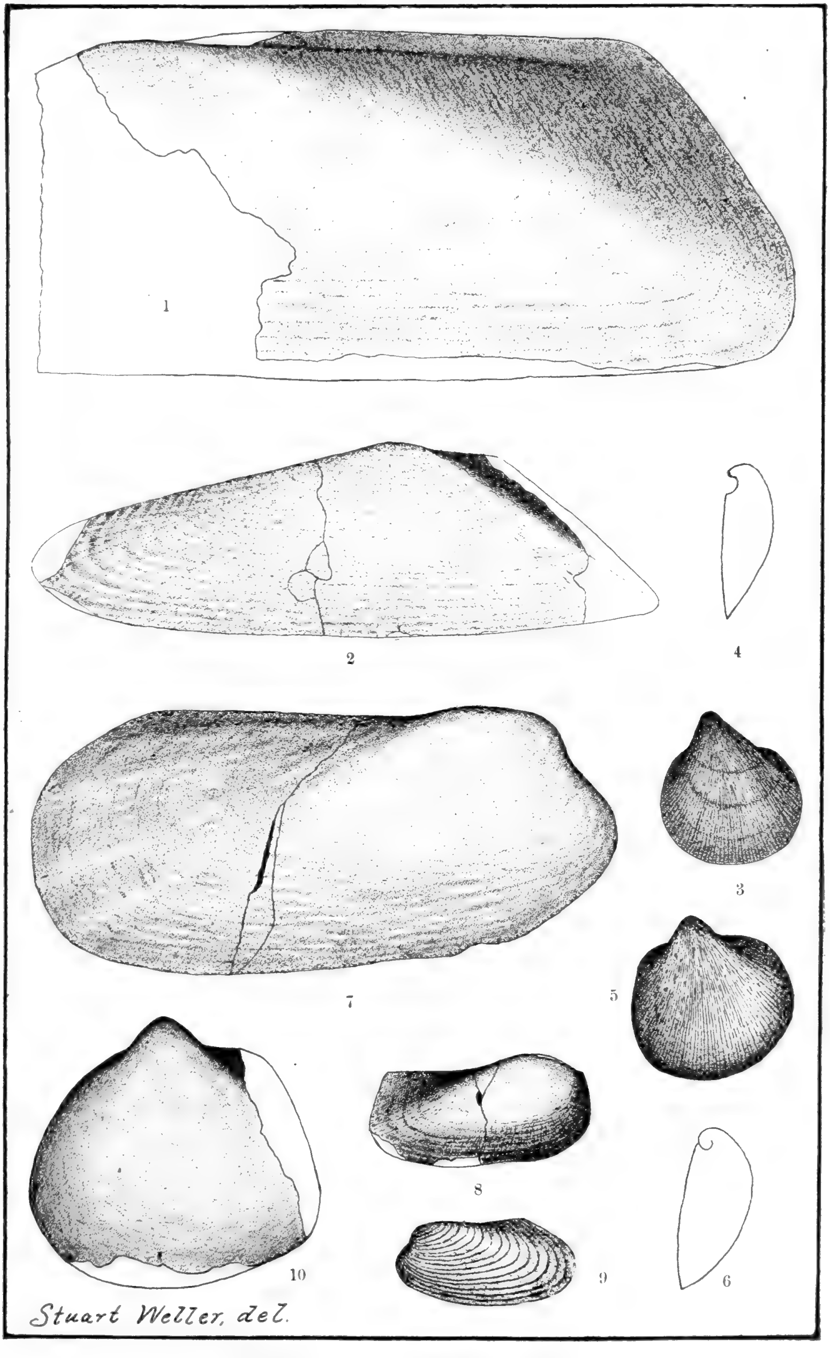


2

S. W. and H. M. W., del.

VERMICULAR SANDSTONE FAUNA.



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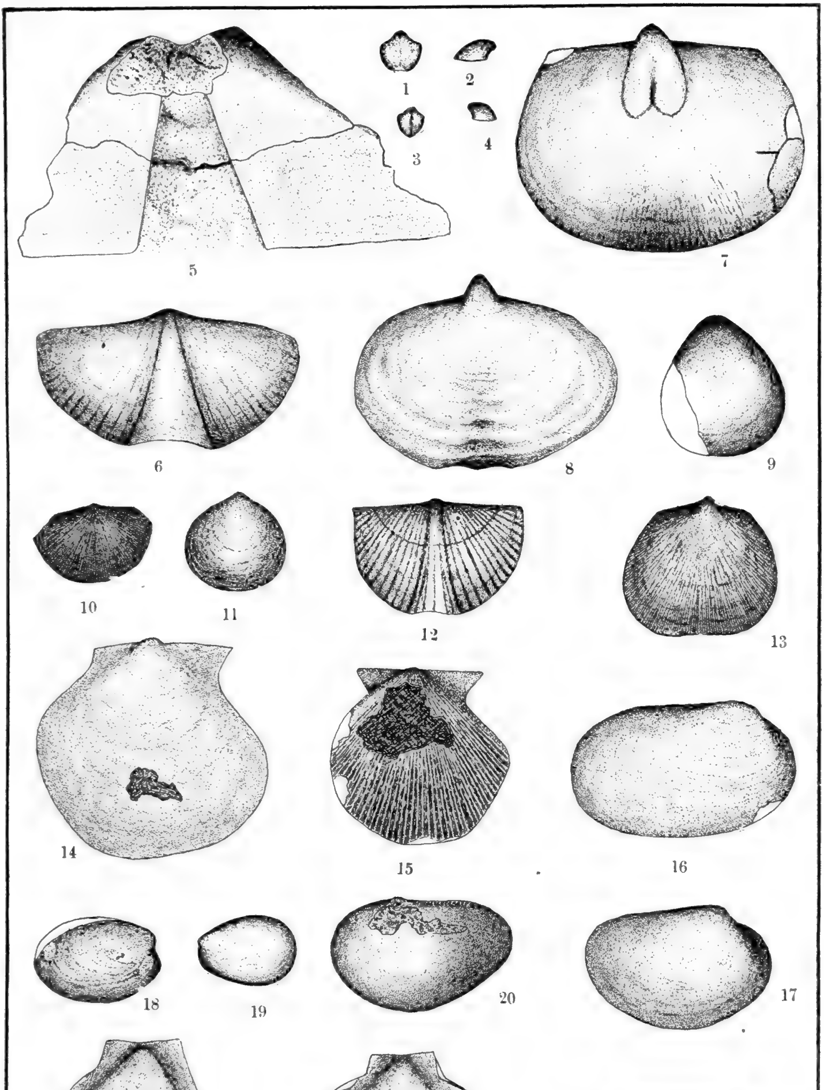

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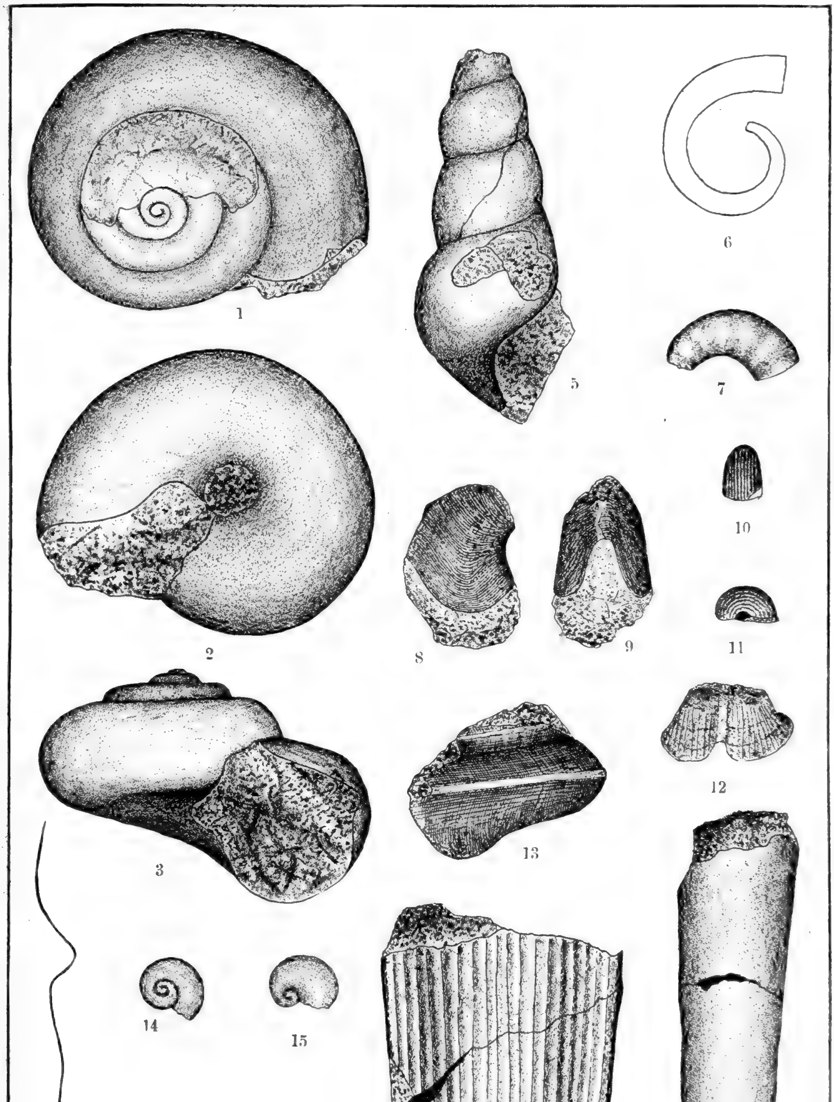
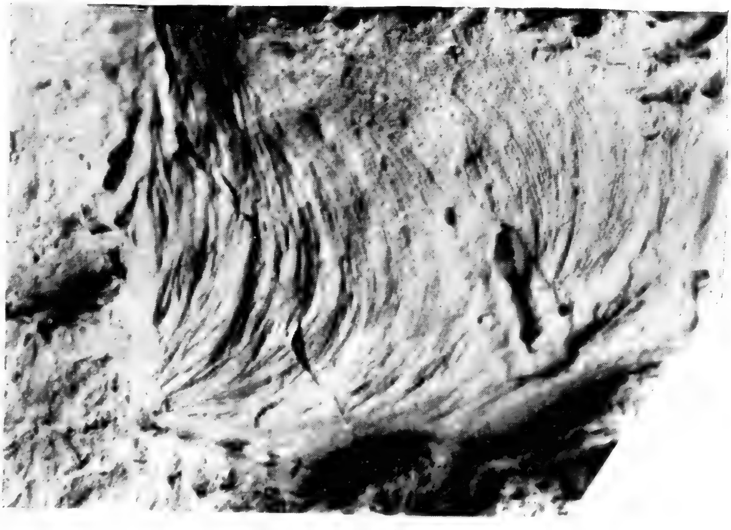


VERMICULAR SANDSTONE FAUNA.

1



2

VERMICULAR SANDSTONE FAUNA.

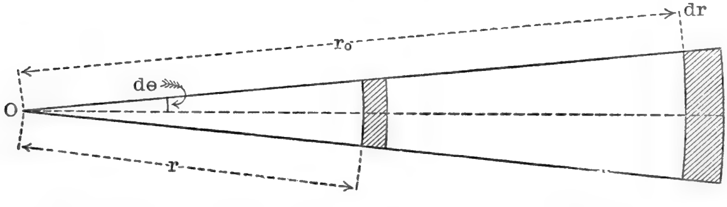
THE RELATIONS OF INTERNAL PRESSURE, VOLUME, AND TEMPERATURE OF AN ISOLATED MASS OF PERFECT GAS OF UNIFORM TEMPERATURE AND IN EQUILIBRIUM UNDER THE ACTION OF ITS OWN FORCES.*

CALVIN M. WOODWARD.

I.

Given an indefinite sphere of gas at temperature T_0, *to find the relation of* p *to* r *for any element*, r being the distance from the center of mass, and p the pressure.

Take for an element the gas inclosed between two consecutive concentric spheres and an indefinitely small cone whose half-vertical angle is $d\theta$, and whose vertex is at O, the center of the spheres and the center of mass.



The volume of the element is $\pi r^2 d\theta^2 dr$, as seen in the figure. If δ be the density of the gas at the point, the mass is

$$\pi \delta r^2 d\theta^2 dr.$$

The attraction between this element and the sphere, of mass M, within the radius r, is

$$\frac{kM\pi\delta r^2 d\theta^2 dr}{r^2},$$

---

* Presented in abstract to The Academy of Science of St. Louis, March 20, 1899.

in which k is the attraction between two units of mass at a unit's distance from each other. This force of attraction is balanced by an excess of pressure on its inner surface. Denoting the variation in p for the distance dr by $-dp$, and equating the two forces, we have

$$\pi r^2 d\theta^2 dp = -\frac{kM\pi\delta r^2 d\theta^2 dr}{r^2},$$

or

$$M = -\frac{r^2 dp}{k\delta dr}. \tag{1}$$

It is evident that in the above expression as r changes, both M and δ change.

Let the equation of the gas be

$$pv = \frac{p}{\delta} = CT, \tag{2}$$

in which v is the volume of a unit of mass; hence since $T = T_0$, we have

$$\delta = \frac{p}{CT_0},$$

and (1) becomes

$$M = -\frac{CT_0}{k} \cdot \frac{r^2 dp}{pdr}. \tag{3}$$

Now M itself is a function of p and r; its differential from geometrical considerations is

$$dM = 4\pi r^2 \delta dr,$$

whence

$$\frac{dM}{dr} = \frac{4\pi r^2 p}{CT_0}. \tag{4}$$

M can therefore be eliminated by differentiating (3) with respect to r and equating the two values of the differential coefficient $\frac{dM}{dr}$.

From (3) we get

$$\frac{dM}{dr} = -\frac{CT_0}{k} \cdot \frac{2pr\frac{dp}{dr} + pr^2\frac{d^2p}{dr^2} - r^2\left(\frac{dp}{dr}\right)^2}{p^2}. \qquad (5)$$

Equating the right hand members of (4) and (5), and reducing, we have

$$\frac{d^2p}{dr^2} + \frac{2}{r}\frac{dp}{dr} - \frac{1}{p}\left(\frac{dp}{dr}\right)^2 + a\,p^2 = 0, \qquad (6)$$

which is the differential equation of the required relation.

In this equation, for convenience, I have written

$$\frac{4\pi k}{C^2 T_0^2} = a. \qquad (7)$$

To find the integral of (6), assume

$$p = Ar^n,$$

whence

$$\frac{dp}{dr} = Anr^{n-1};$$

$$\frac{d^2p}{dr^2} = An\,(n-1)\,r^{n-2}.$$

Substituting in (6) we have

$$An\,(n-1)r^{n-2} + 2Anr^{n-2} - An^2r^{n-2} + aA^2r^{2n} = 0. \qquad (8)$$

Equation (8) is homogeneous in r if $n-2 = 2n$, or $n = -2$. Dividing (8) by Ar^{n-2} and substituting -2 for n, we have

$$+6 - 4 - 4 + aA = 0$$

or

$$A = \frac{2}{a};$$

hence the integral of (6) is

$$p = \frac{2}{ar^2} = \frac{C^2 T_0^2}{2\pi k r^2}, \tag{9}$$

the constant of integration being obviously zero.

Substituting this value of p in (4) we have

$$dM = \frac{2CT_0 dr}{k}, \tag{10}$$

which means that all spherical shells, in a given mass of *perfect* gas in equilibrium and at uniform temperature, have the same mass if they have the same thickness, whatever be the radius, their centers being always at the center of mass.

Integrating (10) from $r = 0$ to $r = r_0$, we have

$$M_0 = \frac{2CT_0 r_0}{k} = \frac{2p_0 v_0 r_0}{k}. \tag{11}$$

From (9) we see that at the center of mass where $r = 0$, we have $p = \infty$; and that $p = 0$ only when $r = \infty$. Hence, whatever be the total mass of the gas, it extends to infinity under the conditions assumed. The general value of M is

$$M = \frac{2CT_0 r}{k}, \tag{12}$$

which is infinite when r is infinite; from which we infer, that if there is at any isolated point any manifestation of a perfect gas in the way of pressure, density or temperature, the total unlimited mass of such gas must be infinite. On the other hand, if the total mass is finite, it can only exist with its temperature zero.

The uniform temperature of our mass has been T_0. Equation (12) shows that had the temperature been higher, say T_1 the mass inclosed in the same sphere of radius r would have been proportionally greater; that is

$$\frac{M}{M_1} = \frac{T_0}{T_1}. \tag{13}$$

This result could hardly have been anticipated. Another deduction will soon be made from Eq. 12.

II.

Can the above mass of gas contract automatically through loss of heat, and be again at rest? If so, what will be the effect upon temperature?

It is not easy to see how such an isolated mass filling all space could lose its energy in the shape of radiant heat; but for the sake of the discussion, we may assume it.

In the process of contraction all particles move directly towards the center, the amount of motion being in all cases proportional to the radius. This follows from the law of distribution of the mass as shown by equation (10) the temperature being uniform, though not necessarily constant. All spherical shells of the same mass will still be of the same thickness, and in all cases the new volume of a unit mass of the gas will be proportional to the cube of its new radius; that is, from purely geometrical reasoning (see figure),

$$\frac{v}{v_0} = \frac{r^3}{r_0^{\,3}}. \qquad (14)$$

As the force of gravity is the only force to produce contraction (i. e., do the work of compressing the gas), let us compare its capacity for doing work with the work of compression required, with a view to finding what change of temperature may be necessary.

Let us suppose that the entire mass has contracted, and that within it the sphere with radius r_0 has contracted to the sphere whose radius is r. Its mass has of course remained constantly M_0. The attraction (i. e., the weight) of a unit mass on the surface of this inner sphere is in general during the contraction

$$\frac{kM_0}{r^2},$$

and the energy exerted by gravity in moving it through a distance $-\,dr$ is

$$-\frac{kM_0dr}{r^2};$$

the integral of this from r_0 to r is

$$E_g = kM_0 \int_{r_0}^{r} \frac{-dr}{r^2} = kM_0 \frac{r_0 - r}{r_0 r}. \qquad (15)$$

This work is quite independent of any change of temperature.

On the other hand, the work of compression is largely dependent on the temperature. Evidently the work of compression is

$$E_c = \int_{v_0}^{v} p\,(-dv) = C \int_{v_0}^{v} \frac{-T dv}{v}, \qquad (16)$$

in which, in general, T will vary. Now in order to determine whether the temperature must fall to make contraction possible, or rise as the consequence of an excess of energy in the force of attraction, let us first suppose the contraction to be isothermal, i. e., let the heat produced by the compressing force be in some way radiated out of the system as fast as generated, so that the temperature (and hence the energy) of the gas is all the while constant, with $T = T_0$. Equation (16) thus, by (14), becomes

$$E_c = CT_0 \int_{v_0}^{v} \frac{-dv}{v} = CT_0 \log \frac{v_0}{v} = 3CT_0 \log \frac{r_0}{r}. \quad (17)$$

In order to compare (12) with (14), substitute the value of M_0 in (11), and we have

$$\left.\begin{aligned} E_g &= 2CT_0 \frac{r_0 - r}{r}. \\ E_c &= 3CT_0 \log \frac{r_0}{r}. \end{aligned}\right\} \qquad (18)$$

Since $\log \frac{r_0}{r} = \log \left(1 + \frac{r_0 - r}{r}\right)$, it is at once evident that for all values of r but little less than r_0 (and contraction must begin from $r = r_0$), the work of compression is greater than the work of gravitation; hence the force of gravitation is insufficient to begin the work of isothermal compression. Much less than sufficient, therefore, would it be to produce isentropic contraction, or any contraction with a rising temperature.

If $r_0 - r = ds$, an infinitesimal contraction, then the two elements of work shown in (18) become

$$\left.\begin{aligned} dE_g &= 2CT_0 \frac{ds}{r_0}. \\ dE_c &= 3CT_0 \frac{ds}{r_0}. \end{aligned}\right\} \qquad (19)$$

Equations (19) show that gravity is competent to do but two-thirds of the work required for an initial compression. It is therefore clear that the gas must lose still more heat in order that contraction by gravity may be possible. *This* loss involves an actual fall of temperature.

We are thus driven to the conclusion that automatic contraction is of necessity accompanied by a fall of temperature in its initial stage. Moreover, if steady contraction from one state of equilibrium to another is analogous to the uniform motion of a body under balanced forces, then every intermediate state is a state of equilibrium, and every element of contraction is an initial one, and the fall of temperature must be continuous. Such is the conclusion that must be drawn from equations (19).

Now, on the other hand, let us examine again equation (12). This asserts that the mass in a central sphere is proportional to the product of the temperature and radius, i. e.,

$$M_0 = \frac{2C}{k} \cdot T_0 r_0.$$

Now, if *from any cause whatever* contraction of the mass takes place, so that the sphere of radius r_0 is reduced in size to a sphere of radius r, and it is then a perfect gas in equilibrium, we must have the same mass

$$M_0 = \frac{2CT_0r_0}{k} = \frac{2CTr}{k}, \qquad (20)$$

or

$$T_0r_0 = Tr,$$

or

$$T = \frac{T_0r_0}{r}. \qquad (21)$$

Equation (21) leads to the conclusion that no contraction can take place without a rise in the temperature. These directly opposite conclusions to which we are led by equations (19) and (21) leave us but one way of escape from contradiction: —

Since no automatic contraction can take place without a fall in the temperature, and since no contraction from any cause can take place without a rise in the temperature, it follows that no automatic contraction can take place at all; and finally this last conclusion would appear to lead to one more, viz.: that a mass of isolated gas in equilibrium can undergo no change of temperature.

The writer does not hesitate to admit that his investigations have led him into unexpected fields and that the conclusions he has reached are not entirely free from suspicion; but he submits them to the examination of his fellow investigators.

In this paper he makes no claim that the formulae given apply to imperfect gases, or vapors. He has discussed an ideal problem, and does not wish his results to be interpreted except in close connection with his assumptions.

Issued, April 28, 1899.

ON GRAVITATION IN GASEOUS NEBULAE.

FRANCIS E. NIPHER.

In No. 3 of Vol. IX of these Transactions, appears a paper by C. M. Woodward, on the distribution of pressures and densities in a gaseous mass of constant temperature T_0, which is assumed to have a spherical form. At the surface of any sphere of radius R_0, whose center is at the center of mass, he finds the density and pressure to be

$$\delta_0 = \frac{CT_0}{2\pi k R_0^2}, \tag{1}$$

$$P_0 = \frac{C^2 T_0^2}{2\pi k R_0^2}. \tag{2}$$

The mass within the surface of radius R_0 Woodward found to be

$$M_0 = \frac{2CT_0R_0}{k}. \tag{3}$$

The weight of a gramme at this surface is therefore

$$g_0 = k\frac{M_0}{R_0^2} = \frac{2CT_0}{R_0}. \tag{4}$$

In these equations k is the gravitation constant, and C is the constant of the gas.

The values of these quantities at any sphere whose radius is R are also

$$\delta = \frac{CT_0}{2\pi k R^2}, \tag{5}$$

$$P = \frac{C^2 T_0^2}{2\pi k R^2}, \tag{6}$$

$$M = \frac{2CT_0R}{k}, \tag{7}$$

$$g = \frac{2CT_0}{R}. \tag{8}$$

These equations are all consistent with each other. For example, as will be at once seen, the value of P_0 in (2) is

$$P_0 = \int_{R_0}^{\infty} g\delta dR, \tag{9}$$

where δ and g are given in (5) and (8). Also the value of M_0 in (3) is

$$M_0 = 4\pi \int_{0}^{R_0} R^2\delta dR. \tag{10}$$

It will be assumed for the purposes of discussion that $R < R_0$.

Let the entire mass contract, so that any mass originally within a sphere of any radius r_0, shall be within a radius r, and assume also that

$$\frac{r_0}{r} = \frac{R_0}{R} = \rho. \tag{11}$$

This means that the same law of density distribution shall prevail in the second state as in the first. Assume also that the temperature shall remain T_0 throughout the mass.

It is evident that the value of δ in (5) is the reciprocal of v, where v is the volume of unit mass and that from (5) and (6) the product

$$Pv = P \times \frac{1}{\delta} = CT_0. \tag{12}$$

The same equation may also be applied to the entire sphere in its initial condition. Let V_0 be its volume. Its average density is three times the density (5) at the surface. Then when applied to the entire sphere by (3) and (2) the equation becomes

$$3P_0V_0 = \frac{3C^2T_0^{\,2}}{2\pi kR_0^{\,2}}\frac{4}{3}\pi R_0^{\,3} = CT_0M_0. \qquad (13)$$

This result agrees perfectly with (12), that equation applying to volume of unit mass, and (13) to the volume corresponding to the average density of mass M_0.

The same equation applied to the mass M_0 when contracted to volume $V = \frac{4}{3}\pi R^3$ gives

$$3PV = P \times 4\,\pi R^3 = CT_0M_0. \qquad (14)$$

Hence the pressure which must be applied to the contracted sphere, in order to hold it in equilibrium, is, by solving (14) and replacing M_0 from (3),

$$P = \frac{C^2T_0^{\,2}R_0}{2\pi kR^3} = \frac{C^2T_0^{\,2}\rho}{2\pi kR^2}. \qquad (15)$$

The pressure at this surface after contraction has taken place, is therefore ρ times as great as was required in the initial state, as will be seen from (6).

The weight of unit mass at the surface after contraction is,

$$g = k\frac{M_0}{R^2} = \frac{2CT_0R_0}{R^2} = \frac{2CT_0\rho}{R}. \qquad (16)$$

This value is also ρ times as great as the value given by (8).

It is evident therefore that the weight of a gramme at any fixed point within the entire mass has, by reason of this shrinkage, been multiplied by ρ.

It follows that the density of the gas at the surface R, where the pressure is now given by (15), must be

$$\delta = \frac{P}{CT_0} = \frac{CT_0\,\rho}{2\pi kR^2}. \qquad (17)$$

The effect of this shrinkage upon the pressure which the superposed layers exert upon the sphere will now be determined.

That pressure is

$$P = \int_R^\infty g\delta dR. \tag{18}$$

As both g and δ have by the shrinkage been multiplied by ρ, it follows that P in (6) must have been multiplied by ρ^2. Putting in the values of g and δ from (16) and (17) the pressure due to gravitation, of these superposed layers, is on integration

$$P = \frac{C^2 T_0^2 \rho^2}{2\pi k R^2}. \tag{19}$$

It is therefore evident that, on account of skrinkage due to gravitation, the gravitating pressure exerted radially inward across any and every concentric spherical surface has become ρ times as great as the internal mass can support, unless the temperature has increased. When he comes to deal with the subject of contraction, Woodward seems to have omitted from his analysis the work done in compressing unit mass, due to increase in weight of superposed layers. At any fixed point in space, the weight of a gramme increases as shrinkage proceeds, because the mass of matter internal to it is increasing. The work pdv done on unit mass in the case discussed by him, does not all come from the action of gravitation upon the unit mass itself. As a result Woodward not only rejects the work of See, but Lane's law as well.

For the initial conditions the equation for a perfect gas gives,

$$\frac{P_0}{\delta_0} = CT_0. \tag{20}$$

Evidently in the second condition of equilibrium

$$\frac{P_0 \rho^2}{\delta_0 \rho} = C\rho T_0 = CT. \tag{21}$$

where

$$T = \frac{r_0 T_0}{r}. \tag{22}$$

It is evident that (7) with T variable is an expression of the law involved in (22) and which was first announced by A. Ritter* in the form

$$Tr = T_0 r_0 = \text{constant}.$$

According to (7)

$$TR = \frac{kM}{2C}, \qquad (23)$$

where k is the gravitation constant whose value is given below, C is the constant for the kind of gas (PvT^{-1}), and M is the mass of the gravitating gas within radius R from the center of mass.

Equation (23) is in a form which makes it available for inquiry into cosmical problems.

It may be of interest to apply these equations to an infinite mass of gas, having the physical constants which hydrogen has under ordinary conditions such as we can supply at ordinary temperatures. Imagine the central core of this mass, to have within a radius equal to that of our sun, a mass equal to that of the sun.

The quantities thus given are

$M = 1.842 \times 10^{33}$ grammes.
$R = 6.972 \times 10^{10}$ cm.
$\frac{1}{k} = 1.543 \times 10^{7}$ in C. G. S. units.
$C = 4.143 \times 10^{7}$ "

By equation (23)

$$T = \frac{Mk}{2CR} = 20{,}675{,}000^\circ \text{ C}.$$

This temperature is certainly much greater than that of the sun.

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* **Ann. der Phys. u. Chemie, Bd. V, 1878, S. 546.**

Putting this temperature in (5), the density at the surface of this sphere is

$$\delta = \frac{CT}{2\pi kR^2} = 0.432.$$

The density of hydrogen under standard conditions ($0°, 760^{mm}$) is 0.000089578.

The pressure at the surface due to the superposed layers is, by (6),

$$P = \frac{C^2T^2}{2\pi kR^2} = 3.706 \times 10^{14}.$$

This is 366,000,000 atmospheres. The density at the distance of one-tenth radius from the center would therefore be 43.2 times that of water at maximum density and the pressure would be 3.66×10^{10} atmospheres. The density at a distance of 92 million miles from the center of mass would, however, be 0.0000376 if the temperature of all space were ten million degrees C. This is about four-tenths the density of hydrogen under standard conditions.

The average density of the gaseous sphere being three times the density at the surface, the average density of the solar hydrogen sphere is 1.296. The average density of the sun itself is about 1.39, or about 7 per cent. greater than that of the hydrogen sphere.

The density of hydrogen gas near the center of the sphere here discussed would probably be much greater than that of solid hydrogen under a pressure of one atmosphere and at its fusing point. Nevertheless it is a gas, for its temperature is far above the critical temperature of hydrogen.

If a sample of it could be collected in a boiler, of adequate strength and infusibility, and it were brought into our interplanetary space, in the shadow of some planet, it would cool to the freezing point of hydrogen. Even then the pressure on the boiler might be enormous. If the boiler be now enlarged by means of a telescope joint until this pressure is taken off, the boiler may be opened. It will be full of solid hydrogen. The pressure of its vapors will, of course, be very much smaller than would be the case in the atmosphere of the hydrogen sun. In fact the pressure of gases of all kinds in interplanetary space must be practically obliterated, by reason of the low temperature. The facilities for refrigeration on the outskirts of our universe seem to be very effective. And this may also serve to aid in understanding the conditions existing on the sun.

If the gaseous mass here discussed were initially under isentropic conditions, it would remain in equilibrium. It could not contract, nor could its temperature change. If it be assumed to lose heat with equal facility from all parts, it will contract and the temperature will rise uniformly throughout. The greater the heat loss per second, the more rapidly will the mass pass through its history of condensation. If heat escapes from the denser parts near the core, with less facility than from the less dense parts, then the temperature throughout the mass at any instant may become a function of the radius. This seems to be the condition around our own sun.

A gas having greater density than hydrogen, under standard conditions, would have a proportionately smaller constant C.

The temperature computed above for the hydrogen sun would be proportionately greater than 20,000,000 degrees. Equation (23) in fact shows that for a fixed radius R of spherical core, in such a gaseous mass, and containing a given internal mass M, the product $T\ C$ is constant for all gases. Hence, δ and P at the surface of the sphere, computed numerically for the hydrogen mass, would have the same numerical values for any other gas, under the conditions which this entire discussion assumes.

The average density of the entire spherical mass would then be independent of the nature of the gas, and would be 1.296 grammes per cubic centimeter, as was above shown.

The conditions surrounding our own sun do not appear to differ in a way that can negative the conclusion that, in order to account for its increased average density and low temperature, some liquid condensation may be assumed to have already taken place. With the law of gaseous distribution here used as a basis of comparison, the density of the gas at the center is infinite, and still the average density of the sun could not exceed 1.296 under conditions of stability, if it were wholly gaseous, and the pressure of 366,000,000 atmospheres were superposed upon it, the temperature being 20,000,000 degrees at least. Of course, if the sun has a liquid core, it must be composed of substance whose critical temperatures are above that of the sun.

The low temperature of the sun seems to be almost wholly compensated, by the obliteration of cosmical or interplanetary pressure.

Issued May 1, 1899.

NOTES ON SOME WESTERN WILLOWS.*

CARLETON R. BALL.

The notes presented here are the partial results of several months' study of western species of Salix. A systematic and comparative study was made of over 30 species and their numerous varieties. Less than half of them are considered in the present paper. There are several exclusively western species which, while perhaps not rare, are yet very imperfectly known, and there are two or three that are of extremely local occurrence. There are also many species of considerable abundance in higher latitudes, the limits of whose extension into the United States are by no means definitely settled. These are some of the questions for future investigation.

The specimens on which this paper is based are those contained in the herbaria of the Missouri Botanical Garden, the Parry herbarium of the Iowa Agricultural College, and the recent western collections of Prof. L. H. Pammel, of the last named institution. To the Director of the Garden, Dr. Trelease, and his assistants, and to Prof. Pammel, I desire to express my gratitude for the many facilities placed at my disposal and for numerous other acts of kindly assistance.

It is thought that the synonymy of the species will be found nearly complete, especially with regard to all recent names, and that the bibliographic references will direct the reader to the principal sources of information concerning each species. In the list of specimens examined only such are cited as have probably been distributed to one or more other herbaria. Miscellaneous individual collections are not cited unless they have been mentioned in the text. In the citation of a specimen a long dash (——) indicates that it was distributed unnamed; an italicized Latin name indicates that it

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* Presented in abstract to The Academy of Science of St. Louis, April 17, 1899.

was distributed under that name rather than under the proper or accepted name; those not otherwise designated were properly named before distribution. Where the parenthesis (♂ only) or (♀ only) occurs it indicates that the remainder of the specimen belongs to some species other than the one under discussion.

S. LAEVIGATA Bebb.

S. laevigata Bebb, Am. Nat. **8**: 202. 1874. — Bebb, Bot. Calif. **2**: 83. 1880. — Bebb, Bot. Gaz. **16**: 103. 1891. — Bebb, Contr. U. S. Natl. Herb. (Bot. Death Valley) 4: 198. 1893. — Greene, Bot. Bay Reg. 299. 1894. — Parish, Zoe **4**: 347. 1894. — Sargent, Silva **9**: 113. *pl. 468.* 1896

Although *S. laevigata* is a well-marked species, collectors seem to find considerable difficulty in correctly determining specimens of it. A glance at the subjoined list will show that it has been distributed under at least five other names. I have, on the other hand, seen specimens of *S. lasiandra*, *lasiolepis*, var. *Bigelovii* and *Humboldtiana* which had been determined and distributed as *S. laevigata*. In our country its nearest relatives are, on the one hand, *S. lasiandra* and, on the other, *S. nigra*.

Mature specimens are easily differentiated from *S. lasiandra* by a laevigate upper surface of the leaf and the absence of glands on blade or petiole. The staminate aments are long, slender, and flexuous, usually drying yellow. The pistillate aments are from one to five inches long when mature and are more slender than those of *S. lasiandra*. The scales of both sexes are usually densely villous. The following character of the young leaves was given in the original description and is conspicuous and nearly constant. "As the buds expand, two or three small scale-like leaves appear clothed beneath and fringed on the margin with ferruginous silky hairs; these soon fall off." The growth is very dense and the long tawny fringe is quite striking as it projects from under the obovate leaf, which frequently attains a length of an inch before becoming glabrous. These obtuse young leaves are generally provided with an abruptly mucronate point. The numerous prominent glands which stud the margin of young leaf and stipule in *S. lasiandra* are wanting here.

SPECIMENS EXAMINED. — Anderson, Santa Cruz, Calif. 1877. — Austin, Mrs., *765*, Calif. Fl. 1896. — Coues and Palmer, Ft. Whipple, Ariz. (——), Sept. 9, 1865. — Engelmann, (——), Santa Cruz, Calif. Sept. 8, 1880. — Hansen, *1510*, Fl. Seq. Gigantea Reg. 1896. — Heller, *3719*, N. Mex. Pl., *S. Bonplandia (na)*, 1897. — Jones, *5020*, West. Fl., *S. nigra* var. *amygdaloides*, 1894; Fl. Calif., *S. nigra*, Bishop, May 15, 1897. — Kellogg and McLean, (——), San Jose, Calif. 1876. — Lemmon, *19*, *20*, Fl. Calif. 1875; *105*, *S. nigra*, Sierra Valley, Calif. 187–. — Orcutt, *13*, (——), Jacumbe, 1889. — Palmer, *465*, Walnut Grove, Ariz. 1876. — Parish Bros., *545*, Pl. So. Calif. 1881. — Parry, *307*, Pac. Coast. Fl. 1882. — Trask, Blanche, Sta. Catalina Id. Calif. 1896, (two specimens labeled *S. lasiolepis* and *S. laevigata* respectively are each a mixture of these two species). — Wright, *S. lasiandra* var. *lancifolia*, San Bernardino, Calif. 1880.

The following specimens represent, by the size and character of the fertile aments, the var. *congesta* Bebb: —

Howell, *1393*, Pac. Coast Pl., Calif. 1889. — Kellogg and Harford, *925*, (——), Calif. 1868–9. — Palmer, *362*., So. Pt. San Diego Co. Calif. (——), 1875.

S. LASIANDRA Bentham.

S. lasiandra Benth., Pl. Hartw. 335. 1857. — Torrey, Bot. Whipple Exped. Pac. R. R. Rept. **4**: 138. (82). 1857. — Bebb in Bot. Calif. **2**: 84. 1880. — Bebb, Bot. Gaz. **16**: 103. 1898. — Greene, Man. Bot. Bay Reg. 299. 1874. — Sargent, Silva **9**: 115. *pl. 469*. 1896. — Hooker and Arnott, (as *S. Hoffmanniana* Sm.), Bot. Beechey 159. 1833 (?). (1841).

S. speciosa Nutt., Sylva **1**: 58. *pl. 17*. 1842.

S. lucida Willd. *β. foliis lanceolatis* Hooker, Fl. Bor.-Am. **2**: 148. 1839 (?). (1840). (Columbia R. habitat).

S. lucida var. *angustifolia* forma *lasiandra* Andersson, Sal. Bor.-Am.* 54. (8). 1858. — Torrey, Bot. Boundary Survey 204. 1859.

S. lucida var. *macrophylla* Anders., Monog. Sal. 32. 1867. — Anders. in DC. Prod. **16²**: 205. 1868. — Bebb, Bot. Gaz. **16**: 103. 1891.

S. arguta var. *lasiandra* Andersson, Monog. Sal. 33. 1867. — Anders. in DC. Prod. **16²**: 206. 1868.

S. lancifolia Andersson, Monog. Sal. 34. *f. 23*. 1867. — Anderss. in DC. Prod. **16²**: 206. 1868.

S. lasiandra var. *lancifolia* Bebb in Bot. Calif. **2**: 84. 1880. — Macoun, Cat. Canad. Pl. 450. 1886. — Parish, Zoe **4**: 347. 1894.

S. lasiandra var. *typica* Bebb in Bot. Calif. **2**: 84. 1880. — Macoun, Cat. Canad. Pl. 449. 1886.

S. lasiandra var. *Lyallii* Sargent, Gard. & For. **8**: 463. 1895. — Sargent, Silva **9**: 115. *pl. 470*. 1896.

S. Lyallii (Sarg.) Heller, Bull. Torr. Bot. Club **25**: 580. 1898.

The treatment given this willow in the Botany of California makes it possible to refer all forms to the three varieties, and

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* Andersson's Salices Boreali-Americanae was published in Proc. Am. Acad. Sci. **4**: 50–78. 1858.

leaves little or no botanical or geographical territory to the type species. If now, as seems likely, our eager botanists persist in raising all varieties to specific rank, the original species will be suppressed altogether, — a piece of piracy that should make the shade of Bentham return to enter vigorous protest. The different varieties have been often and fully described; the species has not. This is due to the fact that the original description was based on immature staminate twigs from California. Before any complete material had been obtained from that region the plant had been found in New Mexico, two or more places in the Rocky Mts., the Saskatchawan R., Fraser R., Vancouver Island, and along the Columbia, — in short, throughout its entire range except the type locality. Further, almost every new collection had received a new name, specific or varietal. Mr. Bebb's Californian material was scanty, and he was naturally influenced by the extended descriptions of Nuttall and Andersson of extra-Californian forms and finally arranged them as varieties. But both here and in his review of them ten years later he distinctly stated his inability to discern more than a single species in all the forms.

In any consideration of this species it must be borne in mind that the leaves of flowering specimens are necessarily young and that even fruiting specimens are rarely accompanied by foliage that can be called mature. The leaves also undergo considerable change in shape during development. Nuttall, whose figures (of foliage) are very accurate, and whose technical and popular descriptions taken together are very complete, especially emphasized these facts and also noted that the leaves are *green on both sides for a considerable time*. Bentham had the sagacity to see and the thoughtfulness to note that his two-inch leaves were "by no means fully developed." Andersson, however, paid no attention to the fact that the specimens of Hartweg, Bigelow (var. *lasiandra*), Fendler and Geyer (*S. Fendleriana*, *S. arguta*) were all young, and continued to describe the leaves as 2–3 inches long. When he did see the mature glaucous leaves of the Lyall and Bourgeau specimens he failed to connect them with what he had already described, and founded *S. lancifolia* and varieties of *S. arguta* and *S. lucida* thereon. Nuttall's work, which he surely must have seen before he published his monograph, he ignores entirely, although it contained figures and descriptions of two forms.

Recollecting that the Californian specimens were young and the Oregon and British Columbian specimens were mature, there is nothing in any of the descriptions to show that what has been regarded as the var. *lancifolia* is other than the *S. lasiandra* of Bentham. Several specimens from different parts of California are practically identical with those from Oregon and Washington. In fact the most pronounced variation I have yet seen is in Greene's 753 from Yreka, Calif. In view of these facts the recent raising of the variety *Lyallii* (*lancifolia*) to specific rank, by Mr. Heller, is to be deplored. In the first place it may be remarked that Dr. Sargent was in error when he stated (Gard. & For. *l. c.*) that Lyall's specimen from the lower Fraser river "was first described by Andersson (Sal. Monog. 34) as *Salix lancifolia*, and in 1868 (DC. Prod. **16**^{2}: 205) as *Salix lucida β macrophylla*." A closer inspection will show that the Fraser river specimen was described in *both* works as *S. lucida macrophylla* and that a Vancouver Island specimen was in both places made the basis of *S. lancifolia*, as I have shown above in the synonymy. It will also be noted that the leaves of the Fraser river specimen which were "6–9′ long, 2–3′ wide" in 1867 had shrunk to only "5–6′ long, 2′ wide" in 1868. However, Mr. Bebb assures us that they are only his variety *lancifolia* after all. Mr. Heller, in order to establish its title to specific rank, says: "I have collected what is said to be *Salix lasiandra* near Lewiston, Idaho, and the variety *caudata* at the original station near Santa Fe, New Mexico, and this western Washington plant is very different from both. As described in the 'Silva' it certainly has sufficient characters to make it worthy of specific rank, for it is said to differ in its 'longer leaves, tapering from the rounded or subcordate base, usually white on the lower surface, and often seven or eight inches in length, in its more glandular petioles, and the rather narrower and less hairy scales of the pistillate aments.'" Now the original stat-tion for the variety *caudata* was not near Santa Fe, New Mexico, but "by streams in the valleys of the Rocky Mountains, toward their western slope, in Oregon, and also the Blue Mountains" (Nuttall, *l. c.*). However, the Santa Fe specimen was var. *caudata*, a staminate one with thick, short-peduncled aments and young leaves about 2 inches long. The *S. lasiandra* from near Lewiston, Idaho, was also staminate, with similar leaves and more slender aments on longer peduncles. So when he collected in Chehallis Co., Wash., his *Lyallii* type, a pistillate specimen with maturing aments 3 in. long, and the leaves so well developed that they are 2–4½ in. long and larger, becoming glaucous, it naturally looked "very different" to him. As for the characters quoted from the Silva, they are by no means constant. A critical study of 33 separate collections, comprising 40 sheets, fails to discover that the large leaved form is more frequently accompanied by a linear, glabrate scale than by a lanceolate, oblong, or oblanceolate hairy one. Most young leaves and many mature ones are narrowed at the base and are frequently narrowly oblong-acuminate rather than tapering regularly from near the base. In Heller's type they are still distinctly *oblanceolate*, acuminate, with no more petiolar glands than usual. These glands, and also the stipules, are generally proportional to the size, of the leaf. Nuttall's figure shows no glands at all.

SPECIMENS EXAMINED. — Allen, *109f*, *109m*, Fl. Cascade Mts., Wash. 1895. — Anderson, Santa Cruz, Calif. (Cult. by Bebb). — Austin, Mrs., *946*, Calif. Fl. (——), 1897. — Elmer, *835*, Fl. Whitman Co., Wash. 1897, (♂ only). — Engelmann, Upper Umqua R., Oreg., Aug. 17, 1880. — Engelmann, Cowlitz R., Oreg., *S. lasiandra* var. *lancifolia*, Jl. 16, 1880. — Greene, *753*, Pl. Calif., *S. lancifolia*, 1876. — Heller, *3211*, Idaho Pl. 1896; *3856*, Pl. Wash., *S. Lyallii*, 1898. — Howell, Fl. N. W. Am., Oreg., *S. lancifolia*, June, 1882. — Howell, Columbia R., *S. lancifolia*, June, 1880. — Jones, *2450*, Fl. Calif. 1881; Fl. Nev., Carson City, May 29, '97. — Lemmon, *209*, Fl. Calif. (——), 1874. — Parish Bros., *546*, Pl. So. Calif., *S. lasiandra* var. *lancifolia*, 1887. — Parry, *3*, *S. laevigata*, and *4* (——), So. Calif. 1882; *303*, *304*, Pac. Coast Fl., So. Calif., 1882. — Suksdorf, Fl. Wash., *S. lasiandra* var. *lancifolia*, 1881.

S. LASIANDRA var. CAUDATA (Nutt.) Sudw.

S. lasiandra var. *caudata* (Nutt.) Sudworth, Bull. Torr. Bot. Club **20**: 43. 1893. — Bebb, Gard. & For. **8**: 372. 1895. — Sargent, Silva **9**: 116. *pl. 470.* 1896.

S. pentandra β caudata Nutt., Sylva **1**: 61. *pl. 18.* 1842.

S. Fendleriana Anderss., Sal. Bor.-Am. 54. (8). 1858.

S. arguta Anderss. (excl. vars.) Monog. Sal. 32. *fig. 22.* 1867. — Anderss. in DC. Prod. **16²**: 205. 1868.

S. lasiandra var. *Fendleriana* Bebb in Bot. Calif. **2**: 84. 1880. — Bebb in Coult., Man. Rocky Mt. Bot. 334. 1885. — Nelson, Prel. Fl. Wyo. 179. 1896.

The rather characteristic foliage of this variety is well shown in Nuttall's figure and his name *caudata* is aptly descriptive of the long and slenderly acuminate apex of the mature leaf, to which he calls attention. The figure in Sargent's Silva is also very accurate as regards both foliage and aments. The rather narrowly lanceolate leaves are from three to seven inches long, slenderly caudate at the apex, rounded or subacute at the base, thicker and more coriaceous than those of *S. lasiandra* proper, remaining dark green below when mature; stipules very small or wanting; petiolar glands not large; aments 1–2 inches long, dense, on shorter peduncles than those of *lasiandra;* fertile scale usually broader, oblanceolate.

The variety ranges from New Mexico northward in the Rocky Mts. to beyond our northern border, and westward nearly to the coast. Its characters are most constant and strongly marked in the Rockies; toward the coast it is less easily distinguished from typical *S. lasiandra.* The only Rocky Mt. specimen in which I have observed serious deviation from the varietal characters is Baker, Earle, and Tracy, 124, in which the half grown leaves are becoming distinctly glaucous beneath. The aments are those of the variety, however.

Specimens examined. — Baker, Earle, and Tracy, *124*, Pl. So. Colo., *S. cordata,* 1898. — Brandegee, Colo. Fl., var. *Fendleriana*, Cañon Cy., 1877. — Davis, *150, S. nigra,* Lincoln Co., Nev., 1880. — Engelmann, Clear Creek at Idaho Spr., Colo., Aug. 22, 1881; Salt Lake City, Utah, June 29, 1880. — Fendler, *816,* Pl. Nov.-Mex. (——), 1847. — Hall, *471,* Pl. Oreg. (——), 1871. Heller, *2941, 3334,* Idaho Pl., 1896; *3637,* N. Mex. Pl., *S. lasiandra,* 1897. — Jones, *5171.* West. Flora, *S. desertorum* (the ♂ only); *5427,* West. Fl., var. *Fendleriana,* 1894. — Nelson, *737,* Fl. Wyo., var. *Fendleriana,* 1894; *3284,* Fl. Wyo., 1897. — Pammel, *207,* Pl. Wyo., 1897.

S. FLAVESCENS Nuttall.

S. flavescens Nutt., Sylva **1**: 65. 1842. — Bebb in Bot. Calif. **2**: 86. 1880. — Bebb in Coult., Man. Rocky Mt. Bot. 336. 1885. — Bebb, Bot. Gaz. **16**: 105.

1891. — Bebb in Contr. U. S. Natl. Herb. **4**: 198. 1893. — Nelson, Prelim. Fl. Wyo. 179. 1894.

S. Nuttallii Sargent, Garden and For. **8**: 463. 1895. — Sarg., Silva **9**: 141. *pl. 482.* 1896.

Fairly common in its different forms throughout the West from New Mexico and California to and into the British possessions. Like its near relative, *S. rostrata*, it has the habit of a tree rather than that of a shrub and, indeed, it attains a height of seventy feet sometimes, according to Sargent. It is grouped systematically with *S. rostrata* and *S. macrocarpa* by the following common characters: capsules tomentose, pedicels slender, styles obsolete or none. To these may be added filaments frequently pubescent. This seems to be constant in *S. macrocarpa*, general in *S. rostrata* and less frequent in the present species. Of the four staminate specimens examined, one showed distinct pubescence, two a slight pubescence of the extreme base, and one was wholly glabrous.

There is some difference between the forms of the Rocky Mts. and those of the coast region. For the greater part the plant as found in the lower plains of the coast is referred to the variety *capreoides* which is discussed below. The more typical *flavescens* of the mountains has large, broad, fertile aments, 1½–2 inches in length; capsules 3–5 lines long; pedicels about 1 line; scales obovate or narrower, densely villous, sometimes dark only at the tip and along the nerves. Nelson's *1255* is a variation of larger dimensions. The mature aments are of only normal length but the buff capsules are 5–6 lines long; pedicels comparatively short, less than 1 line; scales linear-oblanceolate, acute.

SPECIMENS EXAMINED. — Baker, Earle, and Tracy, *554*, Pls. So. Colo., 1898. — Crandall, Fl. Colo., Larimer Co. Mts., Jly. 2, 1896. — Elmer, *84*, Fl. Whitman Co., Wash., 1897. — Engelmann, Rocky Mt. Fl., Colo. (——), opp. Empire, Sept. 13, 1874. — Engelmann, Bard Creek, Empire, Aug. 5, 1874. — City Cañon, near Salt Lake, Utah, June 29, 1880. — Hayden, (——), Laramie Mts., Aug. 24 (1860?). — Jones, Fl. Nev., Carson City, June 2, 1897. — Nelson, Fl. Wyo., *74*, 1894; *1255*, *S. macrocarpa*, and *1586*, 1895. — Pammel, 216, Pl. No. Colo., 1896.

S. FLAVESCENS var. CAPREOIDES (Anders.) Bebb.

S. flavescens var. *capreoides* (Anders.) Bebb, Garden and For. **8**: 373. 1895.

S. Scouleriana Barratt in Hook., Fl. Bor.-Am. **2**: 145. 1838 (in part).

S. brachystachys Bentham, Pl. Hartweg. 336. 1857.— Andersson, Sal. Bor.-Am. 60. (15) 1858. — Anders. Monog. Sal. 82. *f. 48*. 1867. — Anders. in DC. Prod. **16**^{2} **:** 224. 1868.

S. capreoides Andersson, Sal. Bor.-Am. 60 (14). 1858.

S. brachystachys var. *Scouleriana* forma *crassijulis* Anderss., Monog. Sal. 83. 1867. — Anderss. in DC. Prod. **16**^{2} **:** 225. 1868.

S. flavescens var. *Scouleriana* (Barratt) Bebb, Bot. Gaz. **7 :** 129. 1882. — Bebb, Bot. Gaz. **16 :** 105. 1891. — Holzinger, Contr. U. S. Natl. Herb. **3 :** 251. 1895.

S. Nuttallii var. *capreoides* (Anders.) Sargent, Gard. and For. **8 :** 463. 1895.

S. Nuttallii var. *brachystachys* (Bentham) Sargent, Silva **9 :** 142. *pl. 483*. 1896.

For a variety which is neither very well marked nor very widely distributed this has acquired an abundant synonymy. This is due partly to the scanty material to which Andersson had access in 1858, partly to his neglect of Nuttall's work, and partly to a confessedly sentimental desire on the part of Mr. Bebb to perpetuate the name of Dr. Scouler in connection with some western willow.

S. Scouleriana, as is well known, was founded by Dr. Barratt on leaves of *S. Sitchensis* and aments which were later found to be a form of *S. flavescens*. *S. flavescens* Nutt., *S. brachystachys* Benth., and *S. capreoides* Anders. were all described independently, in 1842, 1857, and 1858, respectively. Andersson having discovered, in 1858, the composite character of *S. Scouleriana*, rejected the name and, in 1867, referred the fertile aments of Barratt's species to *S. brachystachys* as var. *Scouleriana* forma *crassijulis*, ignoring Nuttall's name entirely. He still considered Bentham's *brachystachys* and his own *capreoides* to be distinct. In 1880, Mr. Bebb, also rejecting *S. Scouleriana*, restored Nuttall's name and declared *S. brachystachys* and *S. capreoides* to be identical and hence synonymous with *S. flavescens* Nutt.

In regard to the publication of the name *Scouleriana* as a variety of *S. flavescens*, there seems to be as much misunderstanding as there was in regard to the specimens on which the name was originally bestowed. Mr. Bebb, in 1880, had rightly followed Andersson in rejecting it as a specific name. But in 1882 he, wrongly and against his better judgment, used it in establishing the new combination *S. flavescens* var. *Scouleriana* (Barratt) Bebb (Bot. Gaz. **7 :** 129). Later mistakes made matters worse. In one of his last papers in Garden and Forest he admitted his mistake in using the name *Scouleriana* and replaced it by what he considered the next available name — *capreoides* (Anders.). But in giving the synonymy he cites: " *S. flavescens* var. *Scouleriana* Bebb, Watson and Brewer, Bot. Calif. **2**:86." As I have just stated, it was really published, not in the Botany of California, but in the Botanical Gazette some two years later. Almost exactly contemporaneous with the Garden and Forest paper appeared Contr. U. S. Natl. Herb. **3**. No. 4, in which Mr. Holzinger, reporting on a collection of plants, inserts the following (*l. c.* 251): " *S. flavescens* var. *Scouleriana* (Barratt) Bebb, nom. nov." This is a palpable double error, for neither the name nor the combination is new in that place, the former having been published in 1839 and the latter in 1882, as before stated. The mistake is probably due to some misinterpretation of Mr. Bebb's notes.

Finally Prof. Sargent, discovering that *S. flavescens* was a homonym, renamed it *S. Nuttallii* and transferred the variety *capreoides* to the new specific name. Later, finding that *brachystachys* antedated *capreoides* by some fifteen months, he adopted the former as the correct varietal name. While there is no doubt as to its priority, it might have been advisable to wait, before renaming the variations of a polymorphic species, until it was certain that the two names really represented the same variety.

In general, the coast form is characterized by smaller shorter aments, ¾–1½ inches long, and scales broadly obovate. I cannot discover that the scales are less densely villous than those of the mountain type.

SPECIMENS EXAMINED. — Engelmann, *S. Scouleriana*, Seattle, Puget Sd., Jl. 18, 1880. — Heller, *3161*, Idaho Pl., 1896. — Howell, *S. Scouleriana*, Columbia R., Mar. 1880. — Macoun, *486*, Herb. Geol. Surv. Canad., 1893. — Parish, *3002*, Pl. So. Calif., 1894. — Sandberg, Fl. N. A., Nez Perces Co., Idaho, 1892. — Wright, (——), Mt. San Bernardino, Calif. 1880.

S. ROSTRATA Richardson.

S. rostrata Richards., Frankl. Jour., App. 753. 1823.
S. vagans var. *occidentalis* Anders., Sal. Bor.-Am. 62 (16). 1858.

S. vagans var. *rostrata* (Richards.) Anders., Monog. Sal. 87. 1867. — Andersson, DC. Prod. 16^2 : 227. 1868.

S. livida var. *occidentalis* Gray, Man. Bot. 464. 1867 (ed. 5).

S. Bebbiana Sarg., Gard. and For. 8 : 463. 1895. — Sarg., Silva 9 : 131. *pl. 477.* 1896.

The numerous large, elevated leaf scars, which have been emphasized for this species, are very conspicuous on the usually short branchlets. On slender vigorous shoots they are often small or lacking. On the closely related *S. flavescens* Nutt. and *S. macrocarpa* Nutt. they are also large and conspicuous though not usually so numerous. In most western specimens the leaves are only *sparsely* downy above and silky below, much less so than is common in eastern forms. When dry the leaves often have a decided slaty-blue color below. Petioles slender, ¼ in. long. Stipules usually fugacious. In Pammel's No. *198*, Fl. Wyo., they are small, polymorphous (semicordate), coarsely dentate, and silky; numerous on the young leafy twigs.

The staminate aments vary from ½–1 in. long, sessile or short-peduncled, bracteate, yellow, slender until the long capillary filaments become spreading. The filaments are, as noted under *S. flavescens*, frequently pubescent at the base. It was true in four of the seven staminate specimens examined, as follows. — Pubescent: Baker, *6;* Hall and Harbour, *522;* Heller, *3609;* Jones, *1751.* Glabrous: Elmer, *72;* Jones, *5170;* Nelson, *211.* The Hall and Harbour specimen cited above was a mature one from the Parry herb., Ia. State Coll. The *522* in the Engelmann herb., Mo. Bot. Garden, is very young and the filaments are glabrous.

Specimens examined. — Baker, Pl. No. Colo., (Rowlee *4*, *6*, *8*,) (——), 1896. — Baker, Earle & Tracy, *370*, Pl. So. Colo., (——). 1898. — Brandegee, *1010*, *1012*, *S. livida* var *occidentalis*, Colo. 1874; Colo. Fl., Cañon City, 1877. — Elmer, *72*, Fl. Whitman Co., Wash. 1897. — Engelmann, H., Lieut. Bryan's Exped. (——), Black Hills, Aug. 1, 1856. — Engelmann, G., Rocky Mt. Fl. (——), Clear Creek above Empire, Aug. 4, 1874; No. *4*, *7*, Colo. 1881. — Fendler, *815*, Pl. Novo-Mex. 1847. — Hall and Harbour, *522*, Rocky Mt. Flora, 1862. — Heller, *3524*, *3609*, N. Mex. Pl., *S. Nuttallii*, 1897. — Jones, *1751*, Fl. Utah, 1880; *5170*, West. Fl., 1894. — Nelson, *211*, Fl. Wyo. 1894. — Pammel, *212*, *213*, *214*, *215*, Pl. No. Colo. 1896; *198*, *199*, *203*, *211*, Pl. Wyo. 1897.

S. MACROCARPA Nuttall.

S. macrocarpa Nutt.,* Sylva **1**: 67. 1842. — Bebb, Bot. Gaz. **10**: 221. 1885. — Bebb, Bot. Gaz. **16**: 105. 1891.

S. Geyeriana Andersson, Sal. Bor.-Am. 63. (17). 1858. — Anders. Monog. Sal. 86. *f. 50.* 1867. — Anders. in DC. Prod. **16**^{2}: 226. 1868.

As Mr. Bebb has clearly shown us, Andersson ignored Nuttall's Oregon type specimen and transferred Nuttall's name to an entirely different willow from Hudson's Bay. He then described the Oregon willow as *S. Geyeriana*, from Geyer's specimen, of which the staminate aments belonged to *S. rostrata*. Otherwise the two descriptions agree.

This beautiful and well-marked species is found in wet places of the West from So. Calif. to Wash. and the Mts. of Colo. and Wyo. It doubtless occupies the intermediate region and extends farther north. It is a small shrub, 3–8 feet high, with short, divaricately branched twigs usually covered with a glaucous bloom; leaf scars large; leaves lanceolate, or widest just above the middle, 1½–2½ in. long, 3–6 lines wide, acute at both ends, more or less downy above and brown-silky below, at length glaucous below, and glabrous, entire; stipules none; aments appearing with the leaves, subglobose to oblong, ½–¾ in. long, rather dense, looser in fruit, short-pedunculate with silky bracts, peduncle about ¼ in. long in fruit; scales oval-oblong or narrower, obtuse, tawny or dark at apex, long villous; filaments shorter and thicker than in *S. rostrata*, densely pubescent for ⅓–½ their length; capsules slender, silky-villous or glabrate, 2–3 lines long; pedicels pubescent, slender, 1–1½ lines long; stigmas sessile, bifid or entire.

SPECIMENS EXAMINED. — Allen, *107a, 107f, 107m*, Fl. Cascade Mts., Wash. 1895. — Baker, *18, 19, 20*, (Rowlee), Pl. No. Colo. 1896. — Engelmann, Cañon above Grand Lake, Middle Park, Colo., "*S. irrorata* fide Bebb," Aug. 5, 1880. — Hansen, *199*, Fl. Sequoia Reg. 1892. — Howell, *1261*, Pac. Coast Pl., Oregon, 1887. — Nelson, *2095*, Fl. Wyo., *S. Geyeriana*, 1896. — Suksdorf, *698*, Fl. Wash., Falcon Valley. 1883.

S. MACROCARPA var. ARGENTEA Bebb.

S. macrocarpa var. *argentea* Bebb, Bot. Gaz. **10**: 223. 1885. — Bebb, Bot. Gaz. **16**: 105. 1891.

S. Geyeriana Anders. of Bebb, Bot. Calif. **2**: 87. 1880.

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* This is not the *S. macrocarpa* Nuttall of Andersson in Sal. Bor.-Am. 64. (19). 1858. — Monog. Sal. 142. *f. 76.* 1867. — in DC. Prod. **16**^{2}: 245. 1868.

Mr. Bebb thus characterizes the variety: "The beautiful form described in the Botany of California differs in its more conspicuously pruinose twigs, narrower leaves, grayish rather than brownish silky." A specimen from Lemmon, Sierra Co., Calif., has leaves densely silvery silky but does not present the other varietal characters. The staminate twigs of Lemmon's *106*, Fl. Calif. and Nev., *S. arctica* var. *petraea*, belong to this variety of *S. macrocarpa*. It is hardly possible that Lemmon distributed these two entirely different willows as the same species.

SALIX PELLITA Anders.

S. pellita Anderss., Monog. Sal. 139. *f. 72g.* 1867.
S. chlorophylla var. *pellita* Anderss. in DC. Prod. **16**^{2}**:** 244. 1868.
S. Sitchensis var. *angustifolia* Bebb in Bot. Calif. **2:** 87. 1880.

The following notes on this little known species are presented mainly in order to call attention to it and perhaps inspire western collectors to secure more complete specimens of it, if possible.

Andersson described and figured a willow with narrowly oblanceolate leaves, 1 to 2 inches long and 3 to 4 lines wide above the middle, obtuse at the apex and attenuate at the base. As types he cites specimens from Lake Winnipeg (Bourgeau) and the Rocky Mts. (Lyall). A year later, in the Prodromus, Andersson arranges his *S. pellita* as a variety of *S. chlorophylla*. Mr. Bebb, however, considered the plant more nearly related to *S. Sitchensis*. He accordingly described a variety *angustifolia* and cited specimens collected by Dr. Torrey " on a high mountain near Donner Pass," describing the leaves as " acute or acuminate " instead of obtuse, but otherwise agreeing with Andersson's *description*. He also compared with this description the Lyall specimens cited by Andersson as one of the two types and expresses the result thus: " Here we find the leaves 6 to 9 lines or nearly an inch wide, thin and papery in texture, and only the lower spatulate ones obtuse. Similar forms have been collected in Oregon and British America by Hall and Macoun." Other more recent collections all have leaves 1–2½ inches long by 5–9 lines wide and mostly acuminate, and any hesitation we might feel in referring them to *S. pellita* is largely removed by this discovery of Mr. Bebb's that half at least of Andersson's type material corresponds with these later collections and not with the original description and figure.

By 1891, Mr. Bebb had become convinced of his error in founding a variety of *S. Sitchensis* on the Donner Pass specimens. Referring to them, as well as the collections of Lyall, Hall and Macoun, he states (Bot. Gaz. **16**:105–106) that seemingly all these specimens belong "to one species for which *S. pellita* Anders. is the oldest name; unless this is found to be anticipated by the still older and very obscure *S. Drummondiana* Barratt. Furthermore, the very interesting question whether this is a mountain form of the coast *Sitchensis* remains to be demonstrated when we know the staminate aments." So far as known they have not yet been collected. All the specimens I have seen bear foliage only (Clear Creek above Empire, Colo., Engelmann; Dalles of the Columbia, *Engelmann;* Happy Hollow, No. Colo., Pammel No. *219*). The following description is drawn from these specimens as I have not yet had opportunity to consult those referred to by Mr. Bebb.

Shrub; twigs glabrous, greenish-red to dark red, shining, or the younger covered with a glaucous bloom; buds 2–3 lines long; leaves numerous, narrowly oblanceolate (or tapering equally to both ends), acute, or acuminate or the lower obtuse, 1½–2¾ inches long, 4–9 lines wide, margin entire or obscurely crenate, revolute, upper surface dull green and thinly pubescent, becoming glabrous, often drying dark, under surface densely and persistently clothed with a short, appressed, silvery tomentum; stout midrib and slender parallel nerves conspicuously raised below, depressed and often white above; petioles slender, 2–3 lines long; stipules (only on vigorous shoots) semi-cordate, 2–3 lines long, of same texture as leaves.

Andersson thus describes the fertile ament: fertile aments on short, bractless peduncles, thick, very densely flowered, 1 inch long; scales pilose, acute, tawny, dark at apex; capsules tomentose, becoming glabrate, ovate-conical, acute, 1 line long; pedicel short, twice as long as the nectary; style elongated, yellowish; stigmas thick, entire, erect.

S. CHLOROPHYLLA Andersson.

S. chlorophylla Anderss., Monog. Sal. 138. *f. 72.* 1867 (in part). — Anderss. in DC. Prod. **16**²: 243. 1868 (in part). — Bebb, in Coult., Man. Rocky Mt. Bot. 337. 1885. — Macoun, Cat. Canad. Pl. 446. 1886 (in part). — Nelson, Prel. Fl. Wyo. 179. 1894.

S. chlorophylla var. *pychnocarpa* Anderss., Monog. Sal. 139. 1867. — Anderss. in DC. Prod. **16**²: 244. 1868.

It is intended that the above citations be taken as referring to *S. chlorophylla* only in so far as they indicate the western or Rocky Mt. form. The principal works treating of the North Atlantic coast form are cited in a footnote* below.

The story of the confusion of *S. phylicifolia* and *S. chlorophylla* is briefly this. — *S. phylicifolia* was long known in both Europe and northern America. In 1867, Andersson, in his monograph, restricted this name to the European plant and named the American plant *S. chlorophylla*, making the latter include all forms from the White Mts., Labrador, and the west, except a single collection from the Saskatchawan R., which he named var. *pychnocarpa*. Andersson's changes were generally accepted until, in 1889, Mr. Bebb reported on his study of Faxon's abundant collections in the White Mountains. Mr. Bebb asserted that the plant of the White Mts. and Labrador was identical with the European plant and hence should bear the same name, *S. phylicifolia*. Referring to this eastern plant he makes the claim that "from a meeting-ground of perfect similarity the American forms diverge not more widely than do the European of the same species." He does not mention the Rocky Mt. form and only remarks that the variety *pychnocarpa* presents most noticeably the characters of *S. chlorophylla*.

Such Labrador specimens as I have seen are typical *S. phylicifolia*, but the few White Mt. specimens examined, though old and imperfect, present a decidedly American variation towards the Rocky Mt. form. It may be remarked that the description in the Illus. Flora fits the New England plant rather than the typical *S. phylicifolia* of Labrador or Europe.

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* *S. phylicifolia* L., Carey in Gray, Man. Bot. 428. 1848 (ed. 1). — Bebb, Bull. Torr. Bot. Club **16**: 53. 1889. — Bebb in Gray, Man. Bot. 484. 1890 (ed. 6). — Britton & Brown, Illus. Fl. **1**: 502. *f. 1195.* 1896.

S. chlorophylla Anderss. l. c. (loc. White Mts.). — Gray, Man. Bot. 464. 1868 (ed. 5).

The figure of the ament does not accord with the description, being neither sessile, dense, nor oblong-cylindric. It is, however, in the numerous specimens from the Rocky Mts. that the greatest variation is found. To facilitate comparison the characters of both are given below in parallel columns.

S. chlorophylla (Rocky Mts.).	*S. phylicifolia* (Europe).
Mature leaves rarely more than two inches long, usually shorter, mostly narrowed at both ends, entire or rarely slightly crenulate, shining above; aments sessile or the fertile on very short peduncles, bractless or with a few small bracts, very dense, thick, subglobose to oblong cylindrical, not becoming loose in fruit, ¾–1¼ in. long, ½–¾ in. wide; capsules 3 lines long, ovate-conical.	Mature leaves often three inches or more in length, constantly and prominently crenate-serrulate, mostly dull green above, obovate or oblanceolate, obtuse or acute; aments pedunculate, leafy-bracteate, oblanceolate, or cylindrical, elongated, becoming loose in fruit, 1–2 in. long; peduncles ¼–½ in. long; capsules 4–5 lines long, conic-rostrate.

Though the stigmas of *S. chlorophylla* are usually noted as entire, they are either notched or bifid in some Rocky Mt. specimens. This species is found also in the Cascade and Wahsatch Mts. and may be sought in the Sierra Nevada and other coastward mountains.

I think that for the present it will be well to retain the name *S. chlorophylla* for the western mountain form. It is certainly sufficiently distinct to rank as a good variety — perhaps as a separate species.

SPECIMENS EXAMINED. — Baker, Earle, and Tracy, 586, Pl. So. Colo. 1898. — Crandall, Fl. Colo., West of Cameron Pass, July 5, 1894. — Engelmann, Rocky Mt. Fl., Below Berthoud's Pass, Colo. Aug. 10, 1874; No. *9*, Berthoud's Pass, Colo. 1881. — Hayden, Raynold's Exped., Wind. R. Mts., June 1, 1860. — Nelson, *1029*, Fl. Wyo. 1894; *1741*, Flo. Wyo. 1895; *2081*, Fl. Wyo., *S. phylicifolia*, 1896. — Pammel, *217*, Pl. No. Colo. 1896; *218*, *220*, Pl. Wyo. 1897. — Parry, *344*, Rocky Mt. Fl., *S. discolor*, 1861; *6*, Colo. 1864. — Reppert, F., *2*, Berthoude's Pass, Colo. 1898.

S. MONICA, Bebb.

S. Monica Bebb, Bot. Calif. **2**: 90. 1880. — Bebb, Bot. Gaz. **16**: 107. 1891.

This very obscure and doubtful species would seem either to have a restricted range in the higher mountains of California or to be only a form of *S. chlorophylla*. Mr. Bebb suggested the latter possibility in his later paper, though he had seen no other material than the "poor stunted, battered specimens" on which he had founded the species. After examining a *female* specimen (Redfield herb. *7343*, Mo. Bot. Gard.) collected by "John Muir, 1875, alpine near Yosemite, Calif.," the possibility becomes, to me, a strong probability. It has been labeled "*artica?* R. Br.," in pencil by Redfield, but it is very distinct from that species. In habit and leaf characters (except tawny hairs), in "aments lateral, densely flowered, sessile or on very short but distinct peduncles with two oblong leaf-like bracts at base; scales dark colored; capsules ovate-conical, silky-tomentose, sessile; styles medium-sized, not produced; stigmas mostly entire, spreading" it coincides with *S. Monica.* The aments, however, are not "diminutive roundish" but oblong, ¾ in. long; scales not "roundish-ovate, rather obtuse, and slightly villous" but ovate-lanceolate, acute, and villous with long tawny hairs; the capsules not "minute, a line long" but 1½–2½ lines long. In these characters it conicides with *S. chlorophylla*, as it also does in the leaves (all immature) thinly villous with tawny hairs. The descriptive quotations are from the description of *S. Monica.*

These points should be noted: (1), *S. Monica* as described differs from *S. chlorophylla* in the smaller, non-glaucous leaves, shorter aments, capsules, and styles, and the very different scales of the two sexes. (2), These differences, except in the scales, would be the natural accompaniment of "poor stunted specimens" such as Bebb's types confessedly were. (3), The Muir specimen possesses the characters common to both species and also the small, non-glaucous leaves (immature) and short styles of *S. Monica*, with the larger aments and capsules and the scales of *S. chlorophylla.* (4), The normal scales of *S. chlorophylla* are intermediate in shape between the male and female scales of *S. Monica.* The staminate aments of *S. Monica*, with their linear scales, may be found to belong to some other species; several are only imperfectly known.

S. DESERTORUM Richardson.

S. desertorum Richards., Jour. Franklin. Append. 371. 1823.— Hooker, Fl. Bor.-Am. **2**: 151. 1840. — Andersson in DC. Prod. **16**^{2}: 281. 1868. — Bebb in Bot. Wheeler Survey **6**: 241. 1878. — Bebb in Coulter, Man. Rocky Mt. Bot. 338. 1885. — Britton & Brown, Illus. Fl. **1**: 500. *f. 1191.* 1896.

An examination of a large number of specimens of *S. deser-*

torum and *S. glauca villosa* from the Rocky Mts. leads to the conclusion that no rigid line can be drawn between the species as they are represented in that region. The extreme forms are widely divergent but the numerous intermediates present an almost perfect gradation between these extremes. Were it not for a fact to be mentioned later the difficulty might perhaps be settled by regarding the intermediate forms as hybrids. The close relationship between *S. desertorum* and *S. glauca* was recognized by Hooker, and he says (*l. c.*): "Yet there are some varieties, as it appears, which have a different aspect, with much larger, more woolly leaves, and longer and looser catkins." Andersson, under *S. glaucops* (= *S. glauca villosa*), says (DC. Prod. *l. c.*): "Ad *S. desertorum* manifestissimum praebet transitum." Under *S. desertorum* Bebb says (*l. c.* 1878): "To this species should be referred Hall and Harbour's No. *523* (very similar to Drummond's No. 657) and most of the so-called *S. glauca* of the Colorado Mountains." He was certainly right in this statement. Later (*l. c.* 1885) he quotes Hooker and then says that these forms occur "toward the foothills" and present a "manifest transition to *S. glauca-villosa*." That these forms present a transition to the so-called *S. glauca villosa* is true but that they are confined to, or more frequent in, the foothills is a mistake, for numerous specimens have been collected in the highest parts of the Rockies.

From our present knowledge of this species it is apparent that the original type specimens and the descriptions based upon them represent not the common and normal form of *S. desertorum* but rather a reduced and extreme form most widely divergent from *S. glauca*. I have never seen the type, Drummond's *657*, but I have examined Hall and Harbour's *523*, and Engelmann's *6*, both from Colorado, and both said by Mr. Bebb to be very near the type. The specimen of *523* is undoubtedly immature and it is hard to say just what the dimensions of leaf, ament, etc., would have been at maturity. The Engelmann specimen is an acknowledged depauperate, "1–1½ feet high," and though the mature aments are sub globose and nearly sessile, and the leaves are but 6–8 lines long, the latter are anything but linear, being 3–4 lines wide.

Such are the leaves of the fertile twigs; on sterile twigs still attached to the fertile the leaves are fully an inch in length and broad in proportion. Specimens of this extreme are not numerous.

The variety *Wolfii* Bebb is a small, narrow-leaved form with capsules glabrate.

The normal and most common (and what should be considered the typical) form of *S. desertorum* has oblong, elliptical-lanceolate, or somewhat oblanceolate leaves, mostly acute, broad and blunt, rarely attenuate at base, 1–1½ in. long, 5–7 lines wide, nerves elevated below; aments short, thick, oblong-cylindrical, very densely flowered, ⅓–¾ in. long, on bracteate-leafy peduncles 3–6 lines long; scales mostly tawny; capsules sessile or very short pedicelled, 2 or sometimes 3 lines long when mature.

Specimens representing the normal form are as follows: — Engelmann, *3* and *8*, 1881. — Engelmann, Rocky Mt. Fl. (——), Colo., Ag. 30, 1874. — Porter, Twin Lakes, Colo., Jl. 25, 1872. — Cowen (Colo. State Agr. Coll.), Fl. Colo., *S. glauca* var. *villosa*, Jefferson, 1896. — Baker, Pl. No. Colo. (Rowlee), *14*, and *17*, 1896. — Brandegee, *221*, Colo. 1871; *1004*, Colo. 1874 (both labelled *S. glauca* var *sericea*). — Nelson, Fl. Wyo., *1759*, 1895. — Jones, Flora Utah, *1171*, 1879.

From this normal form two lines of variation are found, one including the type specimens and the var. *Wolfii* — that is, the extreme form already discussed; the other varying in the opposite direction toward *S. glauca* with its longer and proportionately narrower, villous leaves, and longer, looser aments of longer capsules. The extreme forms of this latter variation occupy the doubtful ground between the two species of the Rocky Mts., *S. desertorum* and the so-called *S. glauca villosa*. The following list includes specimens that are for the greater part to be referred to *S. desertorum* but which present characters more or less distinctly transitional toward the accompanying forms of *S. glauca*.

SPECIMENS EXAMINED. — Baker, Earle, and Tracy, *216*, Pl. So. Colo., *S. chlorophylla*, 1898. — Baker, *9*[*], *16*, Pl. No. Colo. (——), 1896. — Engel-

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[*] Baker, No. *10*, is not a Salix but *Vaccinium caespitosum* Michx. A small specimen of this *Vaccinium* is also included with Engelmann *6*, *S. desertorum*, 1881. Jones, *1571*, West. Fl., 1894, distributed as *S. desertorum*, is composed of staminate twigs of *S. lasiandra* and pistillate twigs of *S. lasiolepis*.

mann, *8*, 1881; Rocky Mt. Flora, Clear Creek, Aug. 21, and Berthoud's Pass, Aug. 13, 1874. — Fowler, Fl. Canad. *S. glauca* var. *villosa*, Bamff. 1887. — Jones, 308, Fl. Colo. 1878. — Macoun, Herb. Geol. Surv. Canad, *S. glauca* var. *villosa*, Bonaparte R., B. C. 1889. — Pammel, *223*, *224*, Pl. No. Colo. 1896. — Pammel, *225a*, *225b*, Pl. Wyo. 1897.

S. GLAUCA L. var. —— ?

S. glauca var. _pullata_ Anders., Watson in Surv. 40th Par. 5 : 325. 1871. — Porter and Coulter, Fl. Colo. 128. 1874.

S. glauca L., Porter and Coulter, Fl. Colo. 128. 1874.

S. glauca var. _villosa_ Anders., Bebb in Bot. Calif. 2 : 89. 1880 (in part). — Bebb in Coult., Man. Rocky Mt. Bot. 338. 1885 (in part).

This, the prevailing form of *S. glauca* L., in the Rocky Mts., is certainly not identical with the *S. glauca* of Europe. It is, in fact, more nearly related to *S. desertorum* Richards. than to *S. glauca* and, as has already been said, no rigid line can be drawn between it and the first-named species. It has small leaves, lanceolate or oblanceolate, 1–2 in. long, scarcely larger than those of *S. desertorum*, more or less villous on both sides, nerves not elevated below; aments rather slender and loose, ½–1½ in. long; capsules about 3 lines long; styles entire or divided. True *S. glauca* of Europe has rather broadly oblanceolate leaves, 1½–3 or 4 in. long; aments ¾–1 in. wide, loose, 1–3 in. long; capsules, when nearly mature, 4–5 lines long. Our Rocky Mt. form was included under *S. glauca villosa* Anders. by Mr. Bebb, but it is certainly not the *S. villosa* Don described by Hooker (Fl. Bor.-Am. 2 : 144) and later published by Andersson as *S. glauca villosa* (Sal. Bor.-Am. 22). That had long leaves and thick aments 2–3 inches long, being thus more closely related to the European *S. glauca*.

Andersson considered the *S. glauca* of *arctic* North America to be identical with the European species. This is probably true. The description of the arctic form given in the Illust. Flora fits the European species very well except for the capsule "3 lines long," which is entirely too short, as I have already said. But, to repeat, the Rocky Mt. form of *S. glauca* is quite different from the typical *S. glauca* of Europe and therefore presumably also different from the *S. glauca* of arctic America. The following specimens may be safely referred to this form of *S. glauca*.

Parry, *341*, Rocky Mt. Fl., 1861.— Parry, *S. glauca* var., Colo., 1864.— Baker, Earle, and Tracy, *300½* and *570*, *S. desertorum*, 1898. — Pammel, *221*, Pl. No. Colo., 1896.— Reppert, *3*, 1898 (in herb.).

Baker *Nos. 11*, *12*, and *13*, Pl. No. Colo., are three similar and peculiar specimens. The leaves are small, 1–1½ in., but in shape, texture and vesture they resemble those of the var. *villosa* rather than those of the common form.

S. GLAUCA var. VILLOSA Anders.

S. glauca var. *villosa* Anders., Sal. Bor.-Am. 68 (22). 1858. — Bebb in Bot. Calif. **2** : 89. 1880. — Bebb in Coult., Man. Rocky Mt. Bot. 338. 1885 (in the larger dimensions only).

S. villosa (?) Don., Hooker, Fl. Bor.-Am. **2** : 144. 1840 (1839).

S. glaucops Anders. in DC. Prod. **16²** : 281. 1868.

Full discussion must be deferred until more abundant material is accessible. I have already stated that, while the Rocky Mt. form was included under this variety by Mr. Bebb, they are, nevertheless, very distinct.

Hansen's *No. 800*, Fl. Sequoia Reg., 1892, is a plant which nearly answers the original description. Except for the absence of serratures and glands it bears a strong resemblance to a narrow-leaved *S. Californica* Bebb, to which it is, of course, closely related.

S. ARCTICA R. Br. var. PETRAEA.

S. arctica R. Br. var. *petraea* Anderss., Bebb in Coult., Man. Rocky Mt. Bot. 338. 1885.— *S. arctica* R. Br. of Watson in King, Surv. 40th Par. **5** : 326. 1871.— *S. arctica* Pallas (*of Andersson*) var. *petraea* Anderss. in DC. Prod. **16²** : 228. 1868.— Bebb in Bot. Calif. **2** : 90. 1880.

S. phlebophylla Anders. ——— ? (but *not* of the Sal. Bor.-Am. nor in DC. Prod.).—Watson in King, Surv. 40th Par. **5** : 326. 1871.

S. tenera Anders. in DC. Prod. **16²** : 288. 1868 (a narrow leaved form).

S. Brownii Bebb, (not *S. Brownei*, Anderss., Lundstr.) var. *petraea* (Anderss.) Bebb, Bot. Gaz. **16** : 107. 1891.

The methods by which Prof. Andersson succeeded in greatly augmenting the then existing confusion in regard to *S. arctica* R. Br. and *S. arctica* Pallas have been exposed by Mr. Bebb (Bot. Gaz. **14** : 115–117. 1889). The vigor and conciseness of his language render the accusation almost dramatic. But great as was the service he rendered and good as his intentions undoubtedly were, it seems that he only added to the burden of synonymy when he renamed "Mr. Brown's *S. arctica.*" His name was an evident homonym, for, while *S. Brownii* Bebb was published in 1889, *S. Brownei* (Anderss.) Lundstr. had been published in 1877. Sadder still, the latter is even more closely related to *S. arctica* R. Br. than was *S. arctica* Pallas. Indeed, it was first established by Andersson in 1868 as a variety of *his S. arctica* Pallas (= *S. arctica* R. Br.). Mr. Bebb was fully aware of this variety, even if ignorant of its elevation to specific rank, when he named his *S. Brownii*. We can attribute his action only to a strong desire to compensate the wrong done by Andersson to the labor and memory of Robert Brown. But in thus using a name which he knew to be occupied he deliberately laid himself open to the very charge on which he had just scored Andersson so severely, and left the nomenclature of the species in worse shape than he found it. I shall not rename the plant now for I believe the name which has been in use for eighty years (*S. arctica* R. Br.) can yet do duty until both the numerous variations and the synonymy have been given careful study.

As indicated by the numerous descriptions, the leaves of this variety vary much in both size and shape. It is rarely mistaken for any other species, however. It approaches most nearly, in its larger forms, to small specimens of the Rocky Mt. form of *S. glauca*.

SPECIMENS EXAMINED. — Brandegee, *1002*, Sangre de Cristo Range, Aug. 1874; Colo. Fl., Sangre de Cristo Mts., Sept. 1877. — Engelmann, Rocky Mt. Fl., Colo., Parry's Peak, Sept. 15, 1874; Mt. Flora, Aug. 22, 1874. — Hall & Harbour, *520*, Rocky Mt. Alpine Fl., 1862. — Lemmon, *106*, Fl. Calif. & Nev. 187–, (♀ only); *208*, Fl. Calif., 1874 (♀ only). — Macoun, *18a*, Herb. Geol. Surv. Canad., *S. Brownii* Bebb var. *petraea* Bebb, 1890. — Parry, Alpine Fl. Rocky Mts., Colo. Ter., 1872. — Patterson, Colo. Fl., *S. arctica* Pall., 1885.

S. RETICULATA L.

A beautiful and well marked little species mentioned only to name or correct the following: —

Baker, Earle, and Tracy, *299*, Pl. So. Colo. (——), 1898. — Crandall, Fl. Colo., *S. arctica* var. *petraea* And., Boreas, July 24, 1897. — Reppert, F. (——), Berthoude's Pass., Colo., Aug. 4, 1898.

Issued May 16, 1899.

ANATOMICAL CHARACTERS OF THE SEEDS OF LEGUMINOSAE, CHIEFLY GENERA OF GRAY'S MANUAL.*

L. H. PAMMEL.

At the suggestion of Professor Trelease, the writer (*195*)† made a study of the seeds of several leguminous plants in 1885. The genera *Gymnocladus*, *Mucuna*, *Phaseolus*, and *Physostigma* revealed so many interesting points that a comparative study of the genera, chiefly of Gray's Manual, was begun in 1886 and 1887 but, owing to other work, it was dropped and not till the year 1896 did I have an opportunity to take the subject up again. Since 1885 many papers bearing on the subject of seeds have appeared.

It gives me great pleasure to acknowledge the assistance received from Professor Trelease, who has given me every facility of the Missouri Botanical Garden. Such literature as was needed was cheerfully obtained for me. I desire also to thank Miss Charlotte M. King for the reproduction of my drawings, and Mr. C. R. Ball, for several favors shown me.

HISTORICAL.

The first account of leguminous seeds we owe to Marcellus Malpighi (161, 87. *f. 301–302*), 1687, who states that what are now known as Malpighian cells (ducts) are partitioned. Gärtner (67, **2**: 301–352. *pl. 144–156*), 1791, in his classic work, described chiefly the external characters of seeds, but in some cases the structure of the testa, endosperm, and embryo are given. Rudolph Boehmer (21), 1785, in a general way also treats of seeds. Bischoff (17), 1833, briefly describes the testa of *Vicia Faba* and *Cicer arietinum*.

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* Presented to The Academy of Science of St. Louis, by title, Mar. 20, 1899. — A thesis for the degree of Doctor of Philosophy, submitted to the Faculty of Washington University, March, 1899.

† The number in parenthesis refers to bibliography at the end of paper.

A general account also appears in his Lehrbuch der Botanik (18). Schleiden and Vogel (234), 1839, 1842, studied the seeds of several representative *Leguminosae.* Pringsheim (202), 1848, in his inaugural dissertation, describes the testa in *Pisum sativum* and *Vicia Faba,* giving some excellent illustrations; Adolfo Targioni-Tozzetti (257), 1855, of *Vicia polyantha.* Russow (212. 213), 1871 and 1872, in connection with his work on the comparative anatomy of *Marsiliaceae,* refers to the structure and nature of the Malpighian cell, especially the light line. Sorauer (250), 1872, Le Monnier (148), 1872, and Wiesner (285), 1873, incidentally refer to the structure of some leguminous seeds.

Strandmark (254), 1874, studied the seeds of the orders *Cucurbitaceae, Solanaceae, Resedaceae, Capparidaceae, Geraniaceae, Convolvulaceae, Hydrophyllaceae, Violaceae, Caryophyllaceae, Malvaceae, Cruciferae,* and eleven genera of *Leguminosae.* Nobbe (190), 1876, gives some details of a few economic species. In 1874, Sempolowski (247) gave a complete and accurate description of the genera *Lupinus, Vicia, Ervum, Pisum, Trifolium, Medicago, Melilotus, Ornithopus, Anthyllis, Trigonella,* and *Onobrychis.* Chalon (39), 1875, published an extended paper, the first part of which is devoted to the structure of the testa, and the second to the endosperm.

To Haberlandt (83), 1877, we owe an account of the development and structure of the seeds of the genus *Phaseolus.* Günther Beck (8), 1878, described the testa, endosperm, and embryo of the economic genera *Vicia* and *Ervum.* The previous autumn, Junowicz (128), 1877, gave detailed accounts of the Malpighian cells in several *Leguminosae.* Godfrin (71), 1880, in his paper on the testa of angiosperms, described *Lupinus, Vicia, Orobus,* and *Trigonella.* Harz (99), 1885, in his extensive study of the seeds of economic plants, gives accurate and detailed accounts of many leguminous seeds. Tichomiroff (260), 1884, briefly notes the microscopic characters of the seed of *Abrus precatorius.* Mention should also be made of the work of Hanausek (91), 1884, and Moeller (179), 1886, and other pharmacognostical writers who have discussed the seeds of medicinal plants. Mattirolo (169), 1885, made a study of the light line of the seeds of several orders, including the *Leguminosae*, in order to settle some of the conflicting theories concerning this peculiar band. The following species were studied by him: *Lupinus albus*, L., *Phaseolus* sp., *Vicia Faba*, L., *Trigonella Foenum-graecum*, L., *Ervum Ervilla*, L., *Pisum* sp., and *Acacia prismatica*, Hffsg.

Among the later writers who have taken up the seeds of the order, mention should be made of Nadelmann (185), 1890, who describes the anatomy, development, and the transformation of the reserve cellulose in the endosperm and embryo of leguminous seeds during germination. Tschirch (265), 1889, in various parts of his work, discusses the chemistry, structure, and function of the testa, embryo, and endosperm. Mattirolo and Buscalioni (174), 1892, in a splendid monograph, have given us one of the best recent accounts of the structure of different parts of the seed, as well as the functions of different parts of the testa. The paper is accompanied by an excellent bibliography on seeds. Some excellent figures and descriptions are contained in the "Anatomischer Atlas" of Tschirch and Oesterle (267). Two recent papers have come to my notice, one by Pfaefflin (199), 1897, who worked under the direction of Tschirch, and the other by Marlière (164), 1897.

GENERAL HISTOLOGICAL DISCUSSION.

MACROSCLERIDS. MALPIGHIAN CELLS.

Malpighi (161) undoubtedly observed these cells, as his figures and descriptions show, and this led Targioni-Tozzetti (257) to apply the name Malpighian to them. Schleiden and Vogel (234), 1838, in their classic paper, apply the term epidermal; Sempolowski, 1874, calls them palisade or epidermal; Strandmark, 1874, epidermis; Chalon, 1875, carapace; Haberlandt, 1877, and Junowicz, 1877, prism cells, Prismenschichte; Russow, 1871, 1872, and Beck, 1878, Hartschichte; Beck, 1878, Hanausek, 1884, Harz, 1885, Moeller, 1886, Nadelmann, 1890, Kayser, (386), 1893, palisade cells.

The term sclerid was proposed by Tschirch (451) for those mechanical elements which are much shorter than bast cells, as a rule not fusiform but blunt, with walls often greatly thickened, stratified and lignified, with oval or rounded pits. In the strongly thickened forms, pore-canals occur. In a later work (265) he adopts the same classification and expands somewhat on the Malpighian cells.* In the joint work of Tschirch and Oesterle the same term is applied. Haberlandt (85) uses the same term in a general way but calls the Malpighian cells of leguminous seeds "palisade sclerenchyma" and refers these to the same category as those found in the seeds of *Cannabis.*

It is obvious from what has been said that the term palisade should not be used, as it is usually applied to the elongated, thin-walled parenchyma of the leaf, where it has an important function to perform in connection with photosynthesis, while the function of the Malpighian cells is chiefly mechanical. I have, therefore, adopted Tschirch's general classification and for this special case the term "Malpighian." Concisely stated, these cells are longer than broad, with blunt or rounded ends and one or more clear, lucid lines extending across the narrow diameter, the so-called light lines. In the order *Leguminosae* these cells are nearly universal. They vary in size just as the seed does. They are strongly developed in *Gymnocladus* and *Gleditschia*, less so in *Trifolium*, some species of *Phaseolus* and *Medicago*, nearly wanting in *Stylosanthes* and *Arachis*, and absent from *Chapmannia*. Under "light line" I have discussed these cells in various orders besides the *Leguminosae*.

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* Tschirch's classification is as follows: —

A. Sclerids.

1 Brachysclerids. Nearly isodiametric, strongly thickened. Cortex, *Quercus* and pimenta.

2 Macrosclerids. Elongated with blunt ends.
   Palisade cells of leguminous seeds: — *Trigonella, Physostigma.*
   Testa of *Ricinus, Croton,* and spicular cells in the seeds of species of *Welwitschia.* The sclerenchyma fibers of cocoanut fruit. The brittle inner layer of the nutmeg.

3 Osteosclerids. Enlarged at both ends like the human femur. In leaf of tea. Support cells (I-shaped cells, T-shaped cells) occurring in the inner layers of many seeds, as *Abrus* and *Trigonella.*

4 Astrosclerids. Many branched sclerids, the branches mostly with a conical point. In leaves of *Camellia, Dammara,* and bark of pine.

CUTICLE. — The cuticle makes its appearance quite early in the development of the ovule. In the mature seed it is represented by a delicate line, as a rule of nearly equal thickness. On the addition of chlor-iodide of zinc or iodine and sulphuric acid, it is colored yellowish-brown. It is dissolved in Schulze's mixture.

The cuticle has the well-known property of not allowing water to pass through, or only with difficulty. The waxy or fatty nature of the cuticle is repellent to water.* Its thickness is correspondingly increased in the seeds of *Mucuna*, *Gymnocladus*, and *Gleditschia*, where germination proceeds rather slowly. The remainder of the cell-wall in leguminous seeds is not homogeneous but there is a more or less differentiated part which I have designated as the cuticularized portion, though not necessarily chemically the same substance. Mattirolo and Buscalioni (170. 174) designate the cuticle as "strato esterno della membrana di rivestimento" or outer covering membrane, and the cuticularized layer as the "strato interno della membrana di rivestimento" because the structures do not correspond to those of epidermal coverings.

Schips (226), who has investigated the question, concludes that the outer layer is the cuticle, and that the layers below are frequently differentiated into two additional parts one of which is more or less mucilaginous.

The substance of the conical projections colors blue with sulphuric acid and iodine and rapidly dissolves; a less soluble part also colors blue with sulphuric acid and iodine. Schips compares these with the intracellular mucilaginous thickenings in the cell-walls of some orchids, as described by Noack (414) and Magnin (399). The cuticularized layer is conspicuous in many seeds of the order, especially in *Gymnocladus*, *Gleditschia*, *Cassia*, and *Parkinsonia*. True, it does not always reach the development found in the epidermal leaf-cells of *Agave* and *Aloe*, well-known representatives of dry climates, yet the cuticularized layer is well marked. From the interior of this layer occur tooth-like projections that

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* Frémy (337) applies the term cutose to the insoluble material of the cuticle, which is derived from fatty and waxy deposits in the cellulose membrane.

separate pore-canals. The pore-canals extend into the cellulose portion of the cell-wall. The remainder of the cell-wall colors blue, except the light line, when treated with chloriodide of zinc or sulphuric acid and iodine. Such are the reactions in *Cassia*, *Gleditschia*, *Aeschynomene*, *Mucuna*, *Lespedeza*, and many others studied. The cell-walls of the osteosclerids and the sclerotic parenchyma in the nutrient layer of the mature seed of *Baptisia* and of *Cassia marylandica* color blue more rapidly than the walls of Malpighian cells. The cellulose of the cell-wall is slowly acted on by cupric ammonia, zinc chloride, and hydrochloric acid. Sulphuric acid also causes a dissolution of the membranes. In some few cases phloroglucin and hydrochloric acid show that lignin is deposited at the base of the cell as well as in the cuticularized layer, as in *Baptisia leucophaea* and *B. australis*. The reactions are shown more clearly in Tables A and B.

PORE-CANALS AND CELL-CAVITY. — The Malpighian cells are not uniform as to thickness; the cell-cavity is as a rule larger in the lower than in the upper end, but it may widen somewhat near the light line in the upper part of the cell, as in *Gymnocladus* and *Gleditschia*. In a surface section the Malpighian cells are five or six-sided with a large central cavity and radiating, frequently branched canals. Serial cross sections show that the central cavity increases in size inward, at the same time the radiating canals disappear. These canals are certainly not to be compared with the folds occuring in the petals of many flowers, as in *Petunia* and *Pelargonium* (372), or in the leaves of *Pinus* (318), *Aspidium aculeatum*, and other plants (395).

In *Strophostyles pauciflorus* the cell-cavity is large in a seed that is about half grown. The lateral walls show some thickening, more above than below, and the outer wall receives deposits of cellulose at certain points, and as the seed develops, more is added to these points. In a mature seed these meet the cell-wall and usually a complete separation from the original cell-cavity occurs. Some writers speak of "Leistenförmige Verdickungen," a term not entirely inappropriate. The true nature of these canals may be seen in sections treated with Schulze's medium, after thoroughly washing and then staining with methylene blue. The canals are simply remnants of the original cell-cavity containing some plastic material. Their true nature and structure are well shown by Marlière (164. *pl. 1. f. 5c.*).

CELL CONTENTS. — In the unripe seed, asparagin commonly occurs. The nucleus is made out readily, especially when stained with haematoxylin. Chromatophores are more common in the unripe seed but frequently persist in the ripe seed, as in *Trifolium*, *Vicia*, and *Phaseolus*. Other proteid products also occur. So long as the seed is soft, coloring matter is not deposited, but when the drying process begins coloring matter is deposited, in spots, as in *Mucuna*, *Phaseolus*, *Wistaria*, or uniformly in the walls, as in *Vicia*, *Trifolium*, *Medicago*, and *Phaseolus*. The coloring matter varies in different genera and species. The general name anthocyanine has been given to it. Some of the pigments have received special names, as lathyrin, cytisin, and numerous others.

Tannin is always found in greater or less quantity; this is most rapidly deposited during the ripening period of the seed. Likiernik (149) notes the occurrence of lecithin, which was first found by Schulze and Steiger (243) in the testa of some leguminous seeds, and probably occurs in the Malpighian cells. Likiernik obtained a second special product which he has called lupeol, a substance resembling cholesterine; from the pea, phytosterin was obtained; from the common bean, two products were obtained, paraphytosterin and phaseol.

LIGHT LINE. — The light line, "linea lucida," "ligne lumière," "Lichtlinie," of various writers, is the most interesting feature of the Malpighian cell. As a rule but a single line occurs in *Leguminosae*, but in *Gleditschia* and *Cassia* there are two. In *Lespedeza*, *Phaseolus*, and *Pisum*, but one. Junowicz (128) gives three for *Lupinus varius;* Sempolowski (247), two for *L. angustifolius;* and Lohde (396), two for *Quamoclit luteola*. None occurs in *Chapmannia*.

Numerous theories have been advanced as to the chemical nature, physical properties, and function of the light line. These views are by no means harmonious, in part because writers have worked with different plants. The position of the light line varies in different plants. It may occur in the testa, the wall of the ovary, or the wall of a sporangium. In all cases, so far as I am aware, it is connected with a reproductive body, and obviously has some function. It may be of interest to briefly review the theories concerning it.

Mettenius (407) states that perhaps it originates from the pore-canals all appearing at the same height in these cells, but he was unable to make these out in cross sections. Schleiden and Vogel (234. 235, 76), in describing the mature testa of *Lupinus perennis*, *L. rivularis*, and *Acacia Farnesiana*, thought the walls of the upper and lower parts of the cells were unequally thickened, the cavity entirely disappearing in the upper part of the cell. Targioni-Tozzetti (257.–99, **2**: 561) suggested that the light line in *Vicia polyantha* was due to numerous thickened, refractive points found above the middle; below this a wide cavity with a thin wall. Hanstein (363.–99, **2**: 561) gives an explanation of the light line in two places. At first he considered that the Malpighian layer consisted of a double row of cells. Later he attributed the phenomenon to a perforated disc at this point, which transmitted the light.

The earlier accounts of the light line were based on observation. Russow, however, studied the light line under polarized light and tested it with microchemical reagents. He concluded that it had a modified molecular structure, containing less water than the remainder of the cell-wall. In *Marsilia* the light line is anisotropic.* Lohde (396) agrees with Russow in regard to the anisotropic nature of the light line. In *Convolvulus* and *Quamoclit* the Malpighian cell, except the light line, colors blue with sulphuric acid and iodine, the parts being less soluble in the region of the light line than elsewhere. In *Hibiscus Trionum* the light line is cuticularized.

Sempolowski (247), who investigated the light line in *Lupinus* and other *Leguminosae*, states that there is not only a difference in the molecular structure but also a chemical

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* On this general subject see Zimmermann, Beiträge zur Erklärung d. Anisotropie d. organisirten Substanzen, — in Habilitationschrift, Ueber Zweck u. Mechanik d. hygroskopischen Gebilde der Pflanzen. Berlin.

modification of the cell-wall at this point, since with iodine and sulphuric acid the cell-wall colors blue, whereas the light line colors yellow. Haberlandt (83), who studied the development of *Phaseolus vulgaris*, accepts the Russow explanation, that the light line is clearer and contains less water than the other parts of the cell, while it colors blue with chlor-iodide of zinc.

Beck (8) thought the appearance might be due to a chemical alteration, but micro-chemical tests did not reveal its nature, though it has but a slight affinity for water. The light line is more refractive than the rest of the wall and chemical changes have taken place. It has certainly not been demonstrated that there is a difference in the amount of water. It is not cuticularized. When stained with carmine and aniline dyes this portion of the wall does not take the stain as readily as others.

Junowicz (128) found undoubted evidence of cellulose material. The cell-wall at this point was strongly refractive and had a different molecular structure. It was never chemically changed, *i. e.*, cuticularized. Fickel (332) who studied *Cucumis sativa*, speaks of a lignification at this point. Harz (99, **2**: 562) accepted the Russow explanation and adds that it is due entirely to physical changes in the laying down of cell-wall substances; it contains less water. It is significant that in several cases mentioned by him the light line disappeared on the application of nitric acid. Tietz (261) considers it due to a chemical modification. Chalon (39) does not express an opinion. Brandza (26) does not seem to have investigated the subject very thoroughly, but gives it as his opinion that a chemical modification has taken place. Wigand and Dennert (471) suggest that it is due to a series of erect fissures, and that the Russow explanation is not correct. Weberbauer (467), who studied the same species of *Nelumbium*, agrees with Wigand and Dennert.

Wettstein (468) agrees with Russow and Sempolowski that chemical and physical modifications occur. The light line slowly colors blue. The absence of pore-canals in the region of the light line causes it to be more dense, as shown by microchemical tests, and its contact with the neighboring porous part of the cell-wall intensifies the luster of the light line. Mattirolo (401), after some careful studies of the light line in *Tilia*, concludes that in this genus it consists of true lignin; in some other plants it approaches it. In *Leguminosae* no lignification occurs as a rule. Overhage (415), who studied the seeds of *Canna*, agrees with Mattirolo that this portion of the Malpighian cell is lignified but thinks that this does not account for all of its peculiarities, and in part these must be due to a peculiar molecular structure. It is doubtful whether Overhage studied the light lines carefully. Humphrey (382) does not commit himself, but says: "Overhage states that the walls in the region of this line are lignified, as Mattirolo has shown to be true of many other seeds."

Huss (118) states that the appearance of the light line must be explained by its physical properties rather than differences due to chemical composition. Marlière (164, 5) gives a physical explanation. "The true cause of the light line lies in the structure of the secondary membrane of the Malpighian cell. When viewed tangentially the cells have an irregular, strongly reduced cavity which projects into the secondary membrane at the points where the narrow lumen occurs. These points penetrate almost to the primary membrane. They are cut out even to the secondary wall. The canals of the cells are strongly acute, generally half cylindrical, leaning towards the primary membrane. The strong thickening of the membrane which surrounds the cell-cavity forms a homogeneous medium for the transmission of light; it thus becomes strongly refringent, more so than any other part of the wall. The depth of the wall through which the rays of light have to pass multiplies their reflections at the expense of their intensity." This, to him, seems to be a probable explanation. Kayser (386, 88) considers that both chemical and physical modifications have taken place in *Convolvulaceae*.

LIGHT LINE IN OTHER ORDERS. — From the above general review of the subject it will be seen that the views are by no means harmonious. It would be presumptuous on my part to conclude, because the reactions in *Leguminosae* are not the same as Mattirolo has described for *Tilia* or Kayser for *Ipomoea*, that these and other writers have been mistaken in their conclusions. I have therefore compared the Malpighian cells of the orders *Tiliaceae, Sterculiaceae, Malvaceae, Cucurbitaceae, Labiatae, Convolvulaceae, Rhamnaceae, Geraniaceae, Nymphaeaceae, Scitamineae*, and *Marsiliaceae* with those of *Leguminosae*. So far as possible I have taken representatives of the orders heretofore studied.

Tiliaceae. (Mattirolo 401, 10. Brandza 26, 115–116. *pl. 8. f. 6–7*). In a nearly mature seed of *Tilia heterophylla* two rather wide light lines occur, one a little above the expanded part of the cell-cavity, the other beginning near the end of the Malpighian cell. When treated with chlor-iodide of zinc, the upper part slowly colors a bluish-black, as in *Sterculia*. The cell-wall below rapidly responds to the action of phloroglucin, coloring wine-red and the light line fainter, indicating lignin. Mattirolo shows a very striking wine-red color in *Tilia argentea* as well as in the lower part of the cell, though I find the reactions not so strongly marked in the light line, which may perhaps be attributed to the seed being somewhat unripe. The ripe seed of *Tilia Americana*, agrees however with *T. heterophylla*. The chlor-iodide of zinc test is just as positive. The whole broad zone in the upper part of the cell-wall colors bluish-black, which would seem to indicate that it consists partly of cellulose, and that lignification has not proceeded so far.

Ripe seed of *Tilia Americana* shows a very distinct lignin reaction in the lower part of the Malpighian cell. The narrow line just under the cuticle gives the reaction for lignin, but the color is not so bright. Iodine alone colors the Malpighian cells pale yellow. All parts are nearly alike at first, but longer action causes the lower part to become darker in color. When very dilute sulphuric acid is added the narrow light line is conspicuously pale straw color. With stronger acid the cell-wall is rapidly dissolved. Disintegration begins in the region of the upper light line. The middle lamella becomes black and resists its action longest. The walls of the Malpighian cell are greatly thickened.

Sterculiaceae. (Mattirolo 401. Caruel 312. Tschirch and Oesterle 267. Brandza 26, 116–117. *pl. 8. f. 9*). In *Sterculia heterophylla* the Malpighian cells form the second layer. The outer portion consists of parenchyma cells with granular contents. The Malpighian cells are greatly elongated, with two light lines. A wide line occupies the upper part of the cell; below it, occur a series of narrow canals, which contain air. The canals extend into the cell-wall. The dark appearance of the cell at this point is due to the contained air. The narrow light line occurs in the upper part of the cell. With chlor-iodide of zinc it assumes a straw color. The lower part of the light line gradually becomes darker, finally bluish-black. Chemically, it appears therefore to differ from the remainder of the cell-wall. It is not, however, typical cellulose. When treated with phloroglucin the light line appears to color slightly, but this is due to the underlying cells. The light line appears in strong contrast with the colored portions. The lower walls of outer parenchyma layers also show the lignin reaction. The lignin test does not quite correspond to Mattirolo's results on *S. platanifolia*, where the reaction is more pronounced. The nutrient layer contains no lignin, except the vascular elements.

Malvaceae. The following writers have discussed the testa or part of it. Duchartre (327); Lohde (396); Strandmark (254); Mattirolo (401); Harz (99, 2: 736–750. *f. 34–35*); Bretfeld (306); Junowicz (128); Hanausek (361, *f. 1–5*); Rolfs (435); Brandza (26, 111–115. *pl. 7. f. 9–14. pl. 8. f. 1–5*); Mell (406); Guignard (354, 141–153. *f. 66–80*); Godfrin (71).

The narrow, well-marked light line of *Malvastrum angustum* occurs close to the exterior cell-wall of the Malpighian cell. The light line colors brown changing to a dark brown, with chlor-iodide of zinc. The remainder of the wall also takes on the same dark color. The cell-wall becomes so deeply colored that nothing of its structure can be made out. Phloroglucin colors the light line but slightly, the lower part coloring very rapidly. In general the reactions are the same as those given by Mattirolo for *Gossypium*, except that it is not so deeply colored.

In *Gossypium herbaceum* the narrow light line runs close under the exterior wall. This is followed by a wide clear band which extends above the enlarged cell-cavity in the upper third of the cell. On the addition of chlor-iodide of zinc the whole cell-wall colors yellowish-brown, the lower part much darker, the light line taking on a very pale color. The wide band turns blue except the narrow light line, which remains nearly colorless. Phloroglucin causes the narrow light line to color immediately. It also colors the cell-walls below the cell-cavity, the wide clear band remaining nearly colorless. The narrow light line and the lower part of the Malpighian cell are lignified, while the broad band is made up mostly of cellulose.

Cucurbitaceae. The following writers have studied the testa of this order. Targioni-Tozzetti (257); Strandmark (254); v. Hoehnel (379); Fickel (332); Godfrin (71); Hartwich (368); Harz (99, 2 : 767–824. *f. 39–45*); Mattirolo (401, 20); Michelis (410); Junowicz (128); and Holfert (116).

In *Sicyos angulatus*, the whole upper part above the enlarged cell-cavity is lighter in color than the remainder of the Malpighian cell, except a narrow zone in the lower part of the cell. It is easy to distinguish three light lines. Junowicz found two light lines in *Luffa acutangula*. I have verified this for the species. Mattirolo, who studied the genus carefully, finds a very distinct reaction for lignin with the phloroglucin test. In *Luffa acutangula* the Malpighian cells color very rapidly with phloroglucin and hydrochloric acid, the light line less rapidly. In sections where the reaction has taken place with this reagent, the light line can be made out as a somewhat brighter band. In *Luffa* the cells above the Malpighian layer are also lignified, as well as the cell-walls of the nutrient layer.

In *Sicyos angulatus* the phloroglucin test acts rapidly on the Malpighian cells, except the two upper light lines. These resist its action except for a very slight coloration, so that a nearly hyaline band may be seen stretching across the section, and this after the section has been subjected to this treatment for half an hour. Chlor-iodide of zinc colors the Malpighian cell a yellowish-brown except the narrow light line in the upper part of the cell. This colors a pale yellow and ultimately colors like the other parts of the cell-wall. The wide line colors darker and more rapidly than the cell-wall below. Fickel states that it is not cellulose but that this portion of the cell-wall is lignified. In *Sicyos* the light line is not lignin nor is it cellulose, but it appears to be a cuticularized substance.

Labiatae. The following writers have studied the testa and pericarp. Mattirolo (401); Junowicz (128); Holfert (116); Guignard (354, 67–77. *f. 104–129*); Chatin (313, 86–96. *pl. 6. f. 4–9. pl. 7. f. 1–2. pl. 8. f. 1–5*); Harz (99, **2**:866–869). Further references may be found in my paper on *Euphorbia* (416).

The Malpighian cells in this order occur in the wall of the ovary. Junowicz studied *Lallemantia*, and Mattirolo the same genus. *Dracocephalum parviflorum* belongs to the same tribe as *Lallemantia*. It has two light lines, one just underneath the outer row of cells of the pericarp, and one in the lower part of the Malpighian cells. Junowicz found two light lines in *Lallemantia*. With chlor-iodide of zinc the light lines and remainder of the cell-wall color dark brown. With phloroglucin and hydrochloric acid, the light line colors in the characteristic way; the remainder of the cell-wall soon colors in the same way. The whole cell-wall is lignified. The cell-cavity of the Malpighian cell terminates in a number of branched canals. With sulphuric acid and iodine the cell-walls color deep brown, they slowly dissolve in concentrated sulphuric acid.

Convolvulaceae. Several writers have investigated the testa of this order. Lohde (396); Strandmark (254); Mattirolo (401); Harz (99, **2**:751. *f. 36–38*); Holfert (116); Kayser (386).

The light lines in *Convolvulaceae* are very distinct. They are shown and described by Kayser, Strandmark, Harz, and Mattirolo. The hard seeds of *Ipomoea Tuba* are provided with two lines, one occurring underneath the exterior wall. The light line is followed by a somewhat darker band in which enlarged pores and a central cell-cavity occur. The darkness is due to contained air. Below this the cell-cavity enlarges. On the addition of chlor-iodide of zinc, the light line colors like the remainder of the cell-wall, brown at first, then changing to a dark brown with a shade of black. The phloroglucin reaction shows that the upper light line colors rose red but slightly, although the exterior walls are somewhat more colored. The upper part of the Malpighian cell colors pale blue, on the addition of this reagent.

The cell-walls of the nutrient layer are lignified, not only where the bundles occur but from the Malpighian cells to the aleurone layer of the endosperm. With sulphuric acid and iodine the cell-walls color blue. The reaction begins around the cell-cavity, and then passes to the light line region, and the lower cells; the light lines appear for a considerable length of time as a lighter band. Several other interesting points should be mentioned in connection with these Malpighian cells. The lower portion is not always blunt, but may be oblique. On making a cross section and placing in chloral hydrate, faint indications of cross walls in the lower part of the cell can be made out. The cross walls of the cells below all end at the same height. When the cells are macerated in Schulze's medium the lower cells may be separated. This has not been clearly indicated by some of the writers who have studied the testa of this order. We may also note the occurrence of an osteosclerid layer above the Malpighian cells, which supports the trichomatous epidermis.

Geraniaceae. The following works bear on this order. Röber (434); Zimmermann (475); Raunkiaer (430); De Toni (324); Brandza (26, 80. *pl. 5. f. 5–8*).

Röber, 1877, was the first one to call attention to the light line in the testa of this order. Raunkiaer, who studied the development and structure of the testa in this order, speaks of the occurrence of a narrow light line. The short Malpighian cells are covered by small epidermal cells, and a layer of parenchyma. The light line is very narrow and might easily be overlooked, at least in *Geranium carolinianum.* Strandmark did not observe it in *G. sanguineum*, although he shows an apparent thickening at this point. A small cell-cavity occurs in the lower part of the cell. With phloroglucin no reaction takes place, although the lower, light-colored, elongated cells color slightly. With chlor-iodide of zinc the cell-walls, including the light line, color brown, and then change to brownish-black, indicating cellulose. With sulphuric acid and iodine the cell-wall colors blue; the light line colors somewhat later. The elongated colorless cells below also color blue.

Rhamnaceae. Malpighian cells are not universal for the order, since Ward and Dunlop (466) do not indicate them for *Rhamnus*, nor does Lindau (394) for this genus. I did not succeed in finding these cells in *Berchemia;* nor does the work of Miers (411) indicate them for the seeds studied by him. The material of *Rhamnus* at my disposal was not satisfactory. Godfrin (71), who studied *Zizyphus vulgaris*, indicates the presence of a light line in the upper part of the Malpighian cells. The testa is very brittle, and it is difficult to get good sections. When these are obtained it is not difficult to make out a wide light line under the cuticle. Godfrin compared it with that found in *Leguminosae.* Structurally it may be compared with the light line found in that order, but it responds very readily to the phloroglucin test, coloring very deeply. The remainder of the cell-wall colors in the same way, but perhaps somewhat less rapidly. It will be seen that the cell-cavity is very much reduced in these cells, and also that the pore-canals are short. The cuticle and cuticularized layers are strongly developed.

The testa of *Ceanothus americanus* is hard and glossy. The greater part consists of the elongated, thick-walled Malpighian cells, which contain very little pigment. The cuticle and cuticularized layers are well developed. The broad light line occurs immediately under the outer lignified cell-wall. On the addition of phloroglucin, the cell-walls of the Malpighian cells, including the light line, color red, but not so deeply as in *Zizyphus.* The light line colors somewhat more tardily than the remainder of the cell-wall. With chlor-iodide of zinc the light line colors yellow at once, and the remainder of the cell-wall soon follows. The color changes to brownish-black. Sulphuric acid and iodine change the cell-wall to a rather dark brown, the light line much lighter in color. The Malpighian cells do not show the lignin reaction in *Adolphia californica*, where the light line is wide and the cell-cavity large. In the Queensland *Alphitonia excelsa* the Malpighian cells are very long, with the cell-walls and light line but slightly lignified.

Nymphaeaceae. Wigand and Dennert (471, 55. *pl. 6. f. 69*), Weberbauer (467, 231. *pl. 8. f. 11*), and Wettstein (468) have studied the order. In *Nelumbo lutea*, as in *Dracocephalum*, the Malpighian cells occur in the wall of the ovary, which is intimately connected with the testa. Wettstein describes it as part of the testa. The considerably elongated, somewhat dark cells have a rather wide light line, which runs across the middle portion. Weberbauer shows longitudinal pores in the region of the light line. A central canal extends from the upper surface down into the wall. With chlor-iodide of zinc the walls of the Malpighian cells color blackish-brown, and the light line also, somewhat later. Phloroglucin shows no lignin reaction. Concentrated sulphuric acid and iodine color the walls deep brown. The cells of the testa and the wall of the ovary are normally blackish-brown because of the presence of pigment.

Scitamineae. The seeds of this order have been studied by many investigators, because of their ecological, physiological, and anatomical peculiarities. I shall refer only to some of the more important papers: Hegelmaier (370); Mattirolo (401); Overhage (415); Tschirch (449. 450); Humphrey (382); Hirsch (373); Kayser (386); Klebs (134); Gris (347); Wittmack (474); Paul (419); Schumann (442); Treub (447a); Pfeiffer (200); Holfert (116); Le Meunier (408); Russow (212).

Canna indica has been studied by numerous investigators. The very hard seed of this species is covered by a waxy material but this does not obscure the numerous stomata which appear as small pits. On removing the outer covering the stomata come more clearly into view. The Malpighian cells are very much elongated, and where the stomata occur are curved in. The light line extends across the cells a little above the middle. With chlor-iodide of zinc the light line and remainder of the cell-wall color yellowish-brown, very slowly changing to a brown-black. The light line is somewhat more refractive at first. Phloroglucin and hydrochloric acid do not affect the cell-wall; sulphuric acid and iodine color it blue.

Marsiliaceae. Much interest has been manifested in an anatomical study of the wall of the sporangium. This structure has not always been emphasized by writers. Of the numerous writers may be mentioned Bischoff (18, **1**: 94, **2**: 110); Mettenius (407); Luerssen (398, **3**: 611, 619. *f. 191*); Strasburger (446b, 123. *pl. 8. f. 147–149*); Valentine (454); Hanstein (363. 365); Braun (305); Russow (212); Mattirolo (401); Campbell (310. 311, 418. *f. 217B*).

The structure of the sporangium has been treated by many writers. An explanation of the light line was offered by Mettenius, who published several monographs on this and related orders of vascular cryptogams. In *Marsilia quadrifolia* the light line extends across the middle of the Malpighian cells. When treated with chlor-iodide of zinc the cell-walls, including the light line, color bluish-black. With phloroglucin and hydrochloric acid no reaction for lignin occurs in any part of the cell. With concentrated sulphuric acid the cell-walls are readily dissolved. With sulphuric acid and iodine the walls color blue. The Malpighian cells are acted upon much more readily than the other parts of the sporangium.

ECOLOGY AND PHYSIOLOGY of the Malpighian Cells. — The foregoing review shows that these cells occur in different orders of plants, by no means always closely related. This is an excellent illustration of the fact so frequently noted, that the same structure recurs in different plants for the perpetuity of the species. It is a well-known fact that the seeds of some *Leguminosae* are extremely hard, *e. g.*, *Gymnocladus*, *Gleditschia*, *Mucuna*, and *Physostigma*. The seeds of *Canna* are extremely hard; so are those of *Nelumbo*. We recall also the hard seeds of *Ceanothus* and *Geranium*, and the sporangium of *Marsilia*.

Functionally the testa of leguminous seeds, and the fruit of some others, protect the seed against variations due to changes of moisture. Many of the seeds of *Leguminosae* retain their vitality for a long period of time. De Candolle (49) found that the seeds of *Leguminosae* and *Malvaceae* preserved their vitality longer than those of *Cruciferae*, *Compositae*, and *Gramineae*. The imbibition of moisture by the seed, and its drying out, greatly lower its germinative energy, hence the importance of a hard covering (162. 165). Leguminous seeds vary with respect to the amount of water they can take up. It was suggested long ago that this was due to a coating of wax (Nobbe 190, 162). Nobbe and Hänlein (191), and Detmer (56) discuss the subject in all its phases.

In view of the more recent researches on the nature of the product found in the cuticle, these earlier opinions are not far out of the way. Von Höhnel (115) states that the capacity for taking up water resides entirely in the Malpighian cells. The seeds of many *Leguminosae*, like *Mucuna urens* and *Cassia Fistula*, can withstand immersion in salt water for some time without impairing their vitality. Darwin (43a) long ago noted the fact for several seeds, including some *Leguminosae*. Martins (167. 168) and Salter (220) indicate the same facts, and Buchwald (35) has shown how admirably the Malpighian cells of *Mucuna* and other leguminous strand plants are protected because of the strong development of these cells. Taubert (258) also shows the same general facts. There can scarcely be a doubt that the thick-walled Malpighian cells with their cuticle enable the seed to thus overcome unfavorable conditions.

It is evident from the above that strand plants may be disseminated by ocean currents and that some North American species, *e. g. Gleditschia* and *Gymnocladus*,* are disseminated by water. Many of the leguminous seeds are disseminated by herbivorous animals. The Malpighian cells here play no small part in protecting the embryo in the passage of the seed along the digestive tract. I have many times seen cattle eat the pods of *Gleditschia triacanthos*. The sweet gummy material is relished. In Central Iowa it is not uncommon to find the honey locust coming up in the streets and around stables. Warder (281) has mentioned this for *Gleditschia*. The seed of *Prosopis juliflora* is largely disseminated by

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* The seed alone is probably rarely carried by the water, except freshets, but the pods and seeds float.

cattle, as noted by Sargent (221). Cattle feed on the pods when forage is scarce. Some farmers of Texas have proposed to plant the tree extensively so that it may be used for this purpose during the dry season. Its distribution in Texas has, no doubt, been largely brought about by cattle. The excrement forms a most suitable nidus for the germination of the seed. Dr. A. P. Anderson, of South Carolina, informs me that the seed of *Sesbania vesicaria* passes through the digestive tract uninjured.

The wide distribution of *Lespedeza striata* over the Southern States is due, according to Mohr (184), to the excrement of herbivorous animals. I am reliably informed that the seeds of *Cassia Chamaecrista* are disseminated by sheep in Southwestern Iowa. The disseminators in this instance suffered some inconvenience because of the cathartic action of the seed. Grisebach (78) and Morris (184a) have shown that the distribution of *Pithecolobium* in the West Indies is due to herbivorous animals. Morris states that *Acacia arabica* is fed to geese to hasten its germination. The *Ceratonia siliqua* is also disseminated by animals, the hard seed readily passing the digestive tract uninjured (Huth 119). The attractive seeds of *Adenanthera pavonia* L., *Pongamia Corallaria* Miq., and *Abrus precatorius* are disseminated by birds. Buchwald (35) gives a number of additional cases of African seeds disseminated by birds. Dinter (58) states that oxen are very fond of *Acacia giraffae*, and the result is that thousands of young plants spring up in gardens where the manure is scattered. From an ecological standpoint the Malpighian cells certainly have a very important function to perform.

Has the Malpighian layer any other function than that of protection? Mattirolo and Buscalioni (174. 171) state that water enters by way of the micropyle and replaces the air, causing the testa to expand. In some further experiments (175) these writers affirm that when sections are treated with coloring matter it enters through the pore-canals into the underlying cells and tissues of the plant. The light line does not prevent water from entering, but its outward flow is checked. The light line checks transpiration during dry weather. The outer part of the Malpighian cells beyond the light line and below the membrana externa (cuticle) is mucilaginous. This swells, the canals take up the water, and by capillarity it passes into the inner parts of the seed. The light line allows little water to pass. It swells only slightly, but is passively stretched, and in this way causes the enlarging of the canals. When transpiration takes place actively and there is no water to repair the loss, the light line assumes its normal position and the canals close.

OSTEOSCLERIDS.

Various names have been given to these cells by different writers: Sanduhrzellen (Harz), Säulenzellen (Sempolowski), Trägerzellen (various writers), cellules en sablier (Chalon), cellules de soutien (Marlière), Knochenförmigezellen (Tschirch), colonne (Mattirolo and Buscalioni). For reasons stated above, the classification of Tschirch (265, **1**: 204) has here been followed.

The osteosclerids almost universally accompany the Malpighian cells, in the order *Leguminosae*. Some exceptions occur, as in *Arachis*, where these cells are like those of the nutrient layer. In *Phaseolus vulgaris* the cells are prismatic. In some species they are much longer than in others. The length also varies in different parts of the same seed, being greater towards the hilar region, where the parts are not so strongly compressed. Where the Malpighian cells curve, the osteosclerids gradually become shorter and merge into the star-shaped parenchyma of the hilum. In *Phaseolus lunatus* they are somewhat funnel-shaped. In *Trifolium* and *Medicago* these cells are what the Germans call hourglass-shaped (sanduhrförmige). The cells are here broad at the base with a triangular intercellular space. In other cases the intercellular space is somewhat prismatic and large, as in *Lupinus albus* and *Vicia Faba*. In some species it is much reduced. This is often a question of position, since its size and character vary in the same seed.

The walls are thickened and in some cases marked by longitudinal canals. Some of the German writers refer to these cells as "streifig verdickt" (99, **2**: 612). This character is well marked in some tribes, notably *Trifolieae* and

Vicieae. It is much less marked in such genera as *Gleditschia* and *Phaseolus*. In *Medicago* and *Trifolium* these markings are conspicuous.

The cell-walls give the characteristic reaction for cellulose with chlor-iodide of zinc or with sulphuric acid and iodine. In *Mucuna*, *Gleditschia*, and *Cassia*, lignification does not occur as a rule. Slight lignification occurs in *Baptisia leucophaea* and is recorded for *Baptisia australis* by Mattirolo and Buscalioni (174, *pl. 1. f. 5–19*). The cell contains some protein matters, and in some genera tannin and coloring matter. Some species, notably *Phaseolus vulgaris* and *P. multiflorus*, contain crystals of oxalate of lime. In the closely related *P. lunatus* these crystals have not been found, nor in any of the North American species studied.— Table C.

NUTRIENT LAYER.

Tschirch (265, 1 : 301) applied the term "Nährschicht" to the layer following the osteosclerids, to designate its function in the immature seed. In the growing seed the cells of this layer contain not only water but chlorophyll and transitory starch, as I have shown for *Strophostyles pauciflorus*. This starch serves to nourish the growing seed. Holfert (116, 6), who has studied its character in several species, observes that in *Lupinus* it consists of thirty rows of cells. The nutrient layer is by no means confined to this order, as the studies of Holfert as well as those of Schlotterbeck (439) show. As the seed approaches maturity the cells collapse, the cell-cavity appearing as a mere line. In *Lupinus luteus* the layer is reduced one-half, and as much in *Strophostyles*. This layer undoubtedly is also a conductor of elaborated and unelaborated food products. The vascular elements begin at the micropylar end of the seed and extend along the raphe. These cells may also give some mechanical support. In *Mucuna urens* the cells attain considerable development, contain air, and are not compressed. Here they serve to buoy the seed up in water, and thus afford an important means for dissemination. The walls consist of cellulose, as microchemical tests show.

This layer has frequently been called the pigment layer, because of the unusual amount of pigment found here. The general term anthocyanine (Harz 99, **2**: 563) has been applied, and the pigments of several species have received special names. This has been referred to under Malpighian cells. The pigment occurs not only in the cell-wall but in the cavity as well. The coloring matter is formed just preceding maturity when the final products, starch and other reserve materials, are forming. In seeds allowed to mature on the plant this proceeds progressively, but when they are separated it takes place rapidly; in the course of a few minutes the color begins to show in the cells. In sections of *Mucuna pruriens* it rapidly diffuses to the neighboring cells of the cotyledons. The pigment is but slightly soluble in cold water.

Tannin is closely associated with the pigment, and by some has been considered to be a part of it. It likewise occurs in both the cell-walls and cavity. Some tannin has been found in this layer in all the seeds studied, although the quantity is small in some cases.

In some cases protein matter may be made out. Alkaloids like cytisin, robinin, cumarin, and others occur. These also occur in other parts of the seed. In *Melilotus* seeds the cumarin is evident although the seeds have been kept dry for years.

In some cases calcium oxalate is common in the immature seed, especially in the hilar region; but it is always transitory and disappears when the cells lose their function of supplying nutrient material. The general structure and microchemical reactions are shown in Table D.

MYCOTIC LAYER.

In *Phaseoleae* a well-developed layer of compact cells occurs underneath the nutrient layer. The cells are elongated, thick-walled, and rich in protein. These cells resemble the short, thick-walled hyphae in the sclerotia of some fungi. I found this layer well developed in *Phaseolus multiflorus* and other members of the genus as well as in *Wistaria*. It is figured and briefly described by Tschirch and Oesterle (267), but earlier by Haberlandt (83).

FUNICULUS AND ADJACENT PARTS.

Under this head I shall discuss the hilum, the hilar groove, micropyle, funiculus, arillus, and arilloid processes (Zwillingshöcker, tuberculi gemini).

Elsewhere the statement was made that the Malpighian cells curve toward the funiculus and that a double row is formed. According to some writers one row belongs to the testa, the other to the funiculus. I have considered both rows as a part of the testa. In each row a light line occurs. The outer row shortens toward the edges where it meets the funiculus; the inner shortens toward the tracheid island.

A section cut across the hilar groove shows a characteristic bundle of tracheids, the so-called "tracheid island" of Tschirch and Oesterle (267). It is oval in outline, connecting at the upper end with the hilar groove (Nabelspalte of the Germans). The tracheids vary in length, being short in the upper and lower parts and much longer in the center. The island is surrounded by several rows of thin-walled cells. The parenchyma in the hilar region has greatly increased and frequently consists of three differentiated parts, rather loosely arranged: (1), thin-walled parenchyma cells, a continuation of the nutrient layer; (2), thicker-walled, star-shaped parenchyma with numerous large intercellular spaces from which the air is not easily expelled; (3), thin-walled, elongated parenchyma surrounding the tracheid island; these cells elongate tangentially at the lower end. In *Mucuna pruriens* twenty rows of these cells occur below the island.

A cross section through the funiculus of *Mucuna pruriens* shows a well-developed fibro-vascular bundle in the center, which consists of phloem and xylem. The elements of the bundle differ in amount in various parts of the funiculus, and in different seeds. This is true of the species studied by Dahmen (43), — *Pisum sativum*, *Vicia Faba*, *Orobus niger*, and *Lupinus luteus*. The phloem consists of the usual sieve cells and their accompanying elements. The xylem in all species thus far studied consists of spirally thickened tracheids. The bundle is surrounded by a parenchyma sheath. The epidermal cells above the rim have their outer walls thickened. The arillate rim in *Mucuna pruriens* consists of thick-walled sclerotic cells which gradually merge into the thinner-walled epidermis. Between the epidermal cells and the parenchyma sheath occur thin-walled parenchyma cells somewhat elongated in the direction of the vascular bundle.

Before maturity the epidermal cells contain a nucleus, cytoplasm with its chlorophyll grains, starch, sugar and asparagin. Dahmen found calcium oxalate rather common, and according to his observation it is rather intimately connected with the formation of cellulose. It accompanies or occurs in combination with a salt of calcium, *e. g.*, calcium glycose. Asparagin is common during the ripening process of the seed in the parenchyma cells of *Mucuna*.

The funiculus is the channel through which the ovule and the developing seed receive their nutrient material, but the vascular elements, according to Dahmen, are not the only channels, as this function may be carried on by the spongy parenchyma and the epidermis. From the funiculus the elaborated products are conducted into the seed by way of the tracheid island. That these substances also pass laterally through the undeveloped Malpighian cells is highly probable. From the tracheid island they can readily pass down, and then tangentially towards the nutrient layer. The elongated, thin-walled parenchyma cells lead directly to the nutrient layer.

The functions of the different parts of this region in the mature seed have been made the subject of papers by Mattirolo and Buscalioni (174), and Pfaefflin (199), who have shown that water passes through the hilar groove; but the latter has found this to be limited. Water passes in readily through the micropylar opening. The Pfaefflin experiments show that the Malpighian cells next to the micropyle take up the greatest amount of water. It seems pretty well demonstrated from the above experiments that the micropyle is hygroscopic in its character, opening and closing according to external conditions. The hilar groove is also hygroscopic. The radicle occurs in a pocket, and is in close proximity to the micropyle. Exchange of gases is accomplished more readily through the micropyle than through the tracheid island.

Mattirolo and Buscalioni ascribe a physiological function to the tracheid island during the early stages of germination.

We may now consider the ecological relations of the structures adjacent to the funiculus. One of the most important of the appendages is the aril. In the immature seed it is intimately connected with the funiculus. The studies of Pfeiffer (200) show that these basal, appendaged structures of the funiculus occur in some *Leguminosae* hitherto regarded as being without an arillus. In *Pisum* it remains attached to the placenta and does not cover the micropyle. In the second type the micropyle is frequently covered or the hilum is surrounded by a thickened border or rim, as in *Mucuna pruriens.* In some of the *Leguminosae* the funiculus, together with the arillus, has an important function to perform in the separation of the seed from the pod (Bachmann 4. Wiesner 285). In a young fertilized ovule of *Pisum* or *Phaseolus* the funiculus is very large, the former rapidly increases in size, and in full active period of growth the latter is small compared with the immature seed. In *Mucuna pruriens* the arillus, the bordered base of the funiculus, becomes an important strengthening organ. It consists of a series of thick-walled sclerotic cells. On the outside these cells are shorter than within, and at the base curve inward. The remainder of the cells curve obliquely upward. The sclerotic rim is wider at the lower end than above, where the cells are shorter and pass into short epidermal cells provided with pores.

The basal part of the funiculus consists of very large thin-walled and highly turgescent parenchyma cells. Immediately above the tracheid island and below these turgescent cells, a few layers of narrow, elongated, and much smaller parenchyma cells occur, which undoubtedly are the conducting elements. Now what takes place during the ripening period? The contents of the parenchyma elements are discharged, the thin-walled, turgescent parenchyma cells collapse, and the funiculus is practically separated from the seed. The final process of complete separation occurs when the pod contracts, owing to drying out. The arillus falls in and helps to pinch the seed off. This pinching-off process is especially marked in the funiculus of *Pisum*. In *Mucuna pruriens* the pinching-off process is similar, although due to the aril. It should be stated, however, that separation from the pod could not be studied on account of its immaturity.

I have given only a few cases and it should not be assumed that the arillus or funiculus has the same mechanical function and structure in all cases, but both organs differ according to the manner of separation. Some of the general anatomical facts are given by Pfeiffer. The arillus is persistent in the seeds of some *Leguminosae*, as in *Pahudia*, *Pithecolobium* and *Copaifera*. The soft, two-lobed arillus of *Pahudia* is eaten by birds.

INNER INTEGUMENT AND NUCELLUS.

In *Papilionaceae* the inner integument occurs usually as a single row of cells during the earlier stages of development, but is so much compressed in the mature seed that it is difficult to differentiate it from the nucellus. In *Caesalpinieae* the inner integument of the mature seed, although much compressed, may usually be made out more readily. In this suborder it consists of one to four differentiated layers of cells, as in *Gymnocladus*, *Gleditschia*, *Ceratonia*, and *Cassia*.

The nucellus disappears early in the development of the fertilized ovule although it may be present for some time in the chalazal region. As a compressed layer it occurs in *Gymnocladus*, *Lathyrus*, *Vicia*, and *Pisum*. The cells of this layer have lost most of their structure and appear as elongated thread-like bodies. The cells are frequently gelatinized.

ENDOSPERM.

Systematic writers since the time of De Candolle (50. 51) have generally stated that endosperm is absent. Some modern systematic writers have fallen into the same error. Bentham and Hooker (14) state "vulgo parcum v. 0, in generibus paucis copiosum subcartilagineum." Of the *Papilionaceae* these authors say: "albumen saepius parcum v. 0." *Caesalpinieae* "semina varia albumine copioso parco v. 0." Watson and Coulter (283, 122–125) say "mostly without albumen." The *Caesalpinieae* "often with albumen." Britton and Brown

(32, 254, 256, 262) state that endosperm is absent from *Mimosaceae: Caesalpinaceae* with or without endosperm: In *Papilionaceae* seeds mostly without endosperm. Taubert (258, 72, 95) states that the endosperm is usually sparingly developed, or wanting; in some genera, however, present in abundance.

In a discussion of this subject we should not lose sight of the fact that the old test for endosperm, that it could not be recognized with the naked eye, applies to many *Leguminosae.* It would be better in descriptive works to simply say endosperm copious or evident only in cases where it is readily made out. Systematic papers and works are generally a ready means for the identification of plants. It would not help in identification to state that the endosperm in *Vicia* consists of one or two layers of cells, but the question is a very different one when the anatomy of the seed is taken up.

Three writers have made an examination of the seeds of a large number of *Leguminosae* with reference to endosperm. The classic papers of Schleiden and Vogel (234), and Chalon (39) recorded the presence of endosperm in a large number of genera and species. It was also correctly indicated by Duchartre (59), Ralph (204), Baillon (5), Gärtner (67), Bentham (12), Harz (99, 2.) and numerous other monographers.

Many of the species studied by Chalon, and Schleiden and Vogel, had been regarded as exalbuminous, but microscopic study revealed the presence of endosperm in varying amounts. Sempolowski (247. 248), who examined several economic genera, found a small amount of endosperm in the genus *Vicia.* Bischoff (17), and Schleiden and Vogel (234) regarded *Vicia* as exalbuminous. Nobbe (190) regarded *Lupinus* as exalbuminous, but the researches of Sempolowski show that the endosperm is mucilaginous. *Pisum* has always been regarded as exalbuminous and yet it is albuminous. The same writer indicated the presence of endosperm in *Trifolium* in considerable quantity in what Nobbe called the "Quellschichte." In *Ornithopus*, Schleiden and Vogel, Sorauer (250), and Sempolowski indicated endosperm present. The endosperm of *Trigonella foenum-graecum* has long been known. Tschirch uses it to illustrate mucilaginous endosperm in his Angewandte Pflanzenanatomie, but, strangely enough, Wigand (286) considered it to be the inner testa.

The endosperm is not of the same character throughout. In *Gleditschia triacanthos*, *Cassia marylandica*, *Trifolium pratense*, *Medicago sativa*, *Desmodium canescens*, *Lespedeza violacea*, and numerous others, where endosperm is strongly developed, it is differentiated into three parts. Sempolowski indicates this in some species studied by him. Harz likewise indicates this differentiation. In *Lupinus* it consists of a single layer, commonly called the aleurone layer, which, as Guignard (355) has shown, is of wide distribution in plants. It is universal in *Cruciferae* (417) but Strasburger (446a, 339) incorrectly refers to the seed of *Capsella* as being exalbuminous, although he correctly refers to the aleurone layer.

In most of the North American genera studied it is never absent. The aleurone layer is not always sharply marked from the underlying endosperm, *e. g.*, *Astragalus canadensis*. In *Cassia marylandica* and *Gleditschia triacanthos* it is easily distinguishable from the cells underneath and those above. It presents the same characters which I have found in *Cruciferae*, *Rhamnaceae*, *Berberidaceae*, and *Sterculiaceae*. In view of this fact and its wide distribution in other orders, and its great development in seeds with a large amount of endosperm, as in *Gramineae*, *Sterculiaceae*, and *Berberidaceae*, the question naturally arises if this layer has not some function other than the mere storage of reserve proteids. Haberlandt (357) has suggested that the aleurone cells produce diastase during the process of germination and may be classed with the digestion glands of insectivorous plants. The more recent researches of Grüss (350), who has done some excellent work with *Zea mays*, seem to leave no doubt that the aleurone layer is a special secreting organ for the production of diastase. The work of Green (342) partially strengthens the results of Grüss and Haberlandt. Green found that germination was much more rapid when a small amount of endosperm was present.

RESERVE CELLULOSE and mucilaginous endosperm.— Schleiden and Vogel long ago observed that the endosperm of some leguminous seeds becomes mucilaginous on the addition of water. Since then it has been repeatedly observed by Sempolowski, Harz, and Tschirch; and quite recently Nadelmann (185) and Marlière (164) have made a special study of the mucilaginous endosperm. The former studied quite a number of species; the latter, *Ceratonia siliqua*. Nadelmann finds it in all of the tribes except *Geoffrieae* and *Swartzieae*, but not in all genera.

Mucilage* and gums are of wide distribution in the vegetable kingdom, occurring in *Malvaceae* (265, 193. — 64, 93), *Acacia* (265, 213–412), *Symphytum* (265, 203), *Euphorbiaceae* (416, has a bibliography; 339. 99, **2**: 831),*Nymphaeaceae* (467), *Linaceae* (319. 335), *Cruciferae* (322. 345.— 417), *Orchidaceae* (265, 194), *Cucurbitaceae* (99, **2**: 778–793. 332. 379), *Labiatae* (99, **2**: 416. 446), *Acanthaceae* (Bibl. in 416), *Plantaginaceae* (453. 335), *Lythraceae* (317. 353. 390. 426), *Loranthaceae* (314. 85. 154. 370. 400. 385. 393), *Marsiliaceae* (363. 364. 398. 310), *Polemoniaceae* (426. Bibl. in 416. 85), *Algae* (294a. 331, and many others), *Fungi* (307. 308. 301, and many others), *Schizomycetes* (301. 409, and numerous works on the subject).

Its presence in some seeds was long ago observed by Grew (345), and mentioned by De Candolle (322). A glance at Table F shows that the mucilages are not of the same origin nor of the same character. Historically the mucilages and the reserve celluloses are of interest. Schleiden and Vogel (235. 234. 236) applied the term amyloid to the thickened cell-walls found in *Schotia latifolia*, *Mucuna urens*, *Tamarindus indicus*, and some others which color blue with iodine. Payen (198, 211–249. *pl. 1*) stated that all cell membranes consisted of cellulose, and that they were isomeric with dextrin, starch, and inulin. He gives the composition as $C_{24}H_{18}O_9H_2O$, and states that it colors blue with sulphuric acid and iodine. Schleiden (232) however thought there were various modifications, and made three divisions, as follows: (1) a form which does not color blue with sulphuric

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* The references given here indicate where the literature may be obtained. From these other references may easily be had.

acid and iodine; (2) amyloid, which colors blue with iodine; (3) plant mucilages, which swell on the addition of water and do not color with iodine. Von Mohl's views (183) did not differ essentially from those expressed by Payen. Nägeli (187, 209) applied the term (1) amyloid to those carbohydrates which color blue with iodine, *e. g.* starch grains, the thick-walled cells of *Schotia*, *Hymenaea*, *Tamarindus*, and *Mucuna*, the endosperm cells of *Calliandra;* (2) the violet modifications of amyloid, as the starch grains in the medullary rays of *Chelidonium*, the endosperm of *Ixia* and *Gladiolus*, the intercellular mucilages of *Florideae* and the mucilages of *Usnea* and *Ramalina;* (3) mesamylin, which colors yellow or not at all, *e. g.*, the bast fibers of many plants like *Linum*, *Cannabis*, and *Urtica divaricata;* (4) disamylum, which is not colored or else colors yellow or intensely golden yellow, or brownish-yellow, *e. g.* endosperm of palms, *Galium*, *Coffea*, and *Strychnos*. Nägeli makes a brief reference to the mucilage of *Leguminosae*.

Frank (335) who investigated the mucilage of several orders of plants, speaks of the reserve cellulose in the endosperm of *Tropaeolum*. The chemical nature of reserve cellulose has been investigated by many writers. Reiss (432), Hoffmeister (377), Miss Cooley (316), Schulze (441), Winterstein (473), Cross and Bevan (320), Zimmermann (294a), Behrens (302), and Tschirch (265, 193–208. *f. 191–208*) treat of the vegetable mucilages.

The gelatinized membranes are distinguished from the ordinary cell-walls by their physical properties. They swell strongly in the presence of water. They agree in their percentage composition with cellulose, $C_6H_{10}O_5$, but they differ from it in their chemical reactions as well as among themselves. Some of them are colored blue with iodine (amyloid), as in the cotyledons of *Tamarindus*, and endosperm of *Tropaeolum*. Others color blue only on the addition of sulphuric acid or chlor-iodide of zinc, as in the thick-walled endosperm cells of *Gymnocladus*, *Gleditschia*, *Lespedeza*, and many others where endosperm is present in the form of reserve cellulose.

Some of the reserve celluloses are colored yellow, others not at all, with iodine. Some are readily soluble in weak acids, as the endosperm of *Liliaceae* and some related orders examined by Miss Cooley.

In *Polygonatum multiflorum* the membrane was dissolved in one minute when acted on by sulphuric acid, diluted with five parts of water. From this it appears to be Schulze's hemicellulose. According to Winterstein this is sometimes associated with amyloid in certain cell-walls. The mucilage of *Astragalus canadensis* and *Gymnocladus* is readily soluble in sulphuric acid, and this is true of many others of the leguminous seed mucilages examined by myself. Some are nearly insoluble in cupra-ammonia. Zimmermann (294a) states that on the addition of nitric acid a part of the gums are changed into oxalic acid, or mucic acid. A part are changed into both kinds of acids.

Cross and Bevan (320) in their recent work on cellulose make the following

CLASSIFICATION OF THE CELLULOSES.

A. Typical cellulose and the cellulose group. Cellulose of cotton, flax, and hemp fibers.
  a. *Boehmeria, Marsdenia tenacissima, Calotropis gigantea,* Sunn hemp.
  b. (1) Celluloses of woods and lignified tissues generally.
    (2) Celluloses from cereal straws, esparto.
  c. Pseudo-celluloses.
B. Compound celluloses.
  a. Ligno celluloses. Jute fiber (*Corchorus*).
    (1) Glycodrupose. Sclerotic cells of pear.
    (2) Lignocellulose of cereals. Straw.
    (3) Woods and woody tissues, wood gum. Oak, cherry, cereal straw.
    (4) Coniferous woods.
  b. Pectocelluloses and mucocelluloses.
    (1) Flax cellulose.
    (2) Mucocelluloses. Quince or jalap mucilage.
    (3) Amyloid. *Tamarindus indica, Hymenaea Courbaril, Schotia latifolia, Tropaeolum majus.*
    (4) Lichenin. *Cetraria islandica.*
    (5) Carragheen mucilage. *Fucus crispus.*
  c. Adipocelluloses and cutocelluloses.
    (1) Cork.
    (2) Cutose.

The sources and character of the pectocelluloses have been conveniently arranged by Tschirch (265, 204). His table, with some additions, is added to show the relation which the mucilage of the endosperm and the amyloid of the cotyledons of *Leguminosae* bear to those of other plants.

CLASSIFICATION OF PECTOCCELULOSES.

I. Cellulose mucilage. Colors blue with chlor-iodide of zinc and with sulphuric acid and iodine. Insoluble in cupra-ammonia.
  - A. Secondary thickening of cell-walls. Epidermal cell-walls in seed of *Pyrus vulgaris*, *Brassica alba* and other crucifers.
  - B. Mucilaginous intercellular cell-wall substance. Primary cell-wall, *Laminaria* stipites.
  - C. Cell contents, products of distinct mucilage cells. Orchid tubers.

II. True mucilages and gums. Color yellow with iodine, and blue with chlor-iodide of zinc. With hydrochloric acid produce oxalic and mucic acids.
  - A. Secondary thickenings of cell-walls.
    - 1. Epidermal cell-walls, *Linum* and *Plantago*.
    - 2. Subepidermal cells, buchu leaves.
    - 3. Mucilaginous endosperms.
      - a. *Leguminosae: Gymnocladus, Gleditschia, Ceratonia, Lespedeza, Cassia Fistula, C. marylandica, Astragalus, Tetragonolobus, Trifolium, Medicago, Robinia*, etc.
      - b. *Liliaceae: Polygonatum.*
    - 4. Mucilage of single cells or groups of cells in other tissue. *Althaea*, Cinnamon bark, Frangula bark, flowers of *Tilia*, flowers of *Malvaceae*, seed of Cocoa, *Loranthus*, *Viscum*.
  - B. Outer part of the cell-wall.
    - 1. Filaments of algae, *Spirogyra*. Hyphae of many fungi.
    - 2. The gummy resinous product of "colleters," especially young bud scales of *Aesculus*, in which the collagen layer under the cuticle becomes mucilaginous. Also some other epidermal glands. Multicellular glands in which the mucilage occurs in the separating walls of cells: Stems of *Silene*.
  - C. Mucilaginous intercellular cell-wall substance. Primary cell-wall.
    - 1. Carragheen and other Algae.
    - 2. The intercellular cell-wall substance of the mucilaginous endosperms, *Tilia* and Mallow flowers. These may in some cases later become mucilaginous.
  - D. Cell contents from distinct mucilage cells. Gum cells in the axial inflorescence of *Hagenia Abyssinica*.
  - E. The contents of entire tissues.
    - 1. Rhizome of *Symphytum*, *Agropyron repens*.
    - 2. Succulents, *Aloe*.
    - 3. Bulbs, *Allium*, *Scilla*.
    - 4. Algae.
    - 5. Protective gums, *Acajou*, and *Simaruba*.

F. Contents of schizogenic excretory reservoirs.
    1. *Cycadaceae*, *Marattiaceae*, some *Sterculiaceae*, *Araliaceae*.
    2. In schizo-lysigenetic cavities. Rind of *Laminaria* stipites.
G. In lysigenetic passages.
    1. Bark of *Acacia*, *Moringa*, *Cochlospermum*.
    2. In bark and woods, *Prunus Cerasus*, *Herminiera*.
    3. In pith and medullary rays, Tragacanth.
    4. Unknown, gum of *Sterculia urens*.

III. Amyloid. Secondary thickening of cell-walls. Colors blue with iodine. Seeds of *Tropaeolum*, *Hymenaea Courbaril*, *Tamarindus*, *Paeonia*, *Balsamina*, *Primulaceae* (*Primula*, *Androsace*, *Anagallis*, *Glaux*), *Iris acuta*, *Cyclamen neapolitanum*, *Asparagus*, *Gladiolus segetum*, and cambium of many trees.

It will be seen from the above that plant mucilages are diverse as to origin and occurrence. The mucilage in the testa of *Theobromaceae*, *Tiliaceae*, and *Sterculiaceae*, was formerly regarded as belonging to cell contents. It arises from the cell membrane, which finally swells and forms a mucilaginous mass. The occurrence of mucilage in the cell is less common than its production from the secondary cell membrane. The mucilage in the parenchyma cells of *Allium Cepa*, *Scilla maritima*, and the very large mucilage cells of Salep and the tissues of *Symphytum*, the gelatinous cell-walls of *Spirogyra*, the mucilage of *Chondrus crispus*, the mucilaginous cell walls of *Saccharomyces cerevisiae*, and the hyphae of many fungi are all familiar examples of one form and another in which these mucilages occur. Table F shows the reactions of the mucilaginous endosperm in the order *Leguminosae*.

Different opinions have been expressed as to how the material has been laid down. Miss Cooley found in *Liliaceae* and some related orders that it is laid down as secondary structure during the ripening of the seed, and this is also true for *Leguminosae*.

Reserve Cellulose and associated reserve matters. — Tschirch (265, 453) makes the statement that reserve cellulose occurs where the cells of cotyledons are thin-walled and contain no starch or where it is sparingly found. In *Leguminosae* this holds true in general, *e. g.* *Gymnocladus canadensis*, *Gleditschia triacanthos*, *Cassia marylandica*, *Ceratonia siliqua*, *Parkinsonia aculeata* and *Robinia Pseudacacia*. In *Trifolium* *pratense* and *T. repens* the reserve cellulose is associated with some starch in the cells of the cotyledons. Miss Cooley (316) found some exceptional cases in *Trillium* and *Paris*, but she observes that the reserve cellulose is small in amount. Reiss (433, 740) first called attention to its occurrence in *Paris quadrifolia*. In *Leguminosae*, as in other plants, the matters occurring associated with reserve cellulose and mucilaginous endosperm are proteids (aleurone grains and the surrounding plasma) and fat. Not only do the proteids occur in the cytoplasm of the endosperm but in the embryo as well. Of their occurrence in the latter we shall speak presently.

USE OF RESERVE CELLULOSE and mucilage.— Sachs (437), in his classic paper on the germination of *Phoenix dactylifera*, showed conclusively that cellulose may be deposited as reserve matter, and that this substance is completely dissolved during the process of germination. Some years later Frank (335, 175) in his researches on mucilages, especially in *Tropaeolum*, indicated the use of reserve cellulose in this plant. Reiss (432. 433), who worked more especially on the chemistry of the reserve celluloses, indicated a similar use in *Chamaerops humilis*, *Asparagus officinalis*, *Allium Cepa*, *Iris pseudo-acorus*, *Foeniculum officinale*, and of the amyloid of *Impatiens Balsamina*, *Paeonia officinalis* and *Cyclamen europaeum*. Miss Cooley (316) studied some additional species among which the following may be mentioned: *Allium ursinum*, *Lilium Martagon*, *Lloydia serotina*, *Smilacina racemosa*, *Belamcanda chinensis*, *Iris sibirica*, *Galanthus nivalis*, etc.

Heinricher (371) suggested that the mucilage in *Impatiens* assists in dissemination, and that the hard substance is a protection against birds. This is, however, very improbable. The mucilage in *Leguminosae* is protected by the hard outer Malpighian cells, and in *Impatiens* it is likewise protected by the tesa. The Malpighian cells repel water for longer or shorter periods in the *Leguminosae*, but this varies in different species. Seeds in which this mucilage attains its greatest development have well and strongly developed Malpighian cells. The Reiss explanation is probably correct, namely, that the plant stores away its food in the most condensed form to save space. Cellulose is much more condensed than starch, proteids or fats.

ECOLOGY OF MUCILAGINOUS SEEDS. — That mucilage in the seeds of many plants is of considerable use has been abundantly proven. In many small cruciferous seeds, as in *Lepidium*, *Capsella*, and *Sisymbrium*, where the outer walls of the epidermis become mucilaginous, the seeds adhere to any moist object. This must also be the function of mucilage of the smaller seeds in *Euphorbia*, as in *E. glyptosperma*, *E. maculata*, and *E. polygonifolia*, where it is produced in considerable quantity.

The objection may be raised for large cruciferous and *Euphorbia* seeds that they do not adhere very readily, because of their size. In proportion to their size the quantity of mucilage in these larger seeds is much less than in the smaller, at least so far as I have investigated the species of *Euphorbia* represented in Gray's Manual (416) and the *Cruciferae* of the same work (417). The larger seeds are disseminated in other ways. The smaller seeds of *Ruellia*, with copious mucilaginous spiricles, are as easily disseminated as the seeds of *Euphorbia*. The mechanism for dispersal of seeds in *Arceuthobium* is well known. The seed when ejected is thrown several feet, the viscid mucilage in which it is embedded causing it to stick to the bark of a tree when brought in contact with it.

Grütter (353) has suggested that the mucilage hairs of *Lythraceae* are for the purpose of fastening the seed to the soil, which is doubtless true to some extent for cruciferous seeds, *Salvia*, *Ruellia*, and *Euphorbia*. Köhne (390) suggests that the mucilage of the seeds of *Lythraceae* renders them more buoyant. In *Nymphaea* and *Euryale* the arillus becomes mucilaginous and floats on the water. The mucilage of the well known squirting cucumber becomes highly turgescent because of its great affinity for water and when mature the stalk separates from the plant and thus scatters the seed. It is a little more difficult to explain the use of mucilage in the cucumber as we now know it. It is not improbable that it served a similar purpose at one time. The mucilage formed in the cross layer of cells at the base of petioles, and the consequent deliquescence, help to separate leaves from the stem. The mucilage produced at the tip of the aerial roots of corn no doubt helps to fasten them to the ground (367).

In none of these cases can the mucilage be compared with that found in *Leguminosae*. It has been suggested that the mucilage in *Loranthus* and *Viscum* is a water reservoir (400, 85). That it may also serve the same purpose in leguminous seeds can hardly be doubted. When once the water passes the Malpighian cells and reaches the endosperm the latter has a great affinity for it and additional amounts are taken up readily. In this respect it may be compared with the mucilage cells of succulents (452. 463). After the endosperm has taken up water the aleurone layer secretes a ferment which dissolves the cell-walls, and the soluble material is conveyed to the embryo.

EMBRYO.

The embryos of the seeds of our *Leguminosae* are extremely variable from a structural standpoint. In the common food *Leguminosae*, *e. g.*, *Pisum*, *Vicia*, and *Phaseolus*, the outer row of cells is somewhat elongated. The outer walls are thickened and with no intercellular spaces between the cells of the first row. The cells below are larger, with small intercellular spaces at their angles. In *Phaseolus multiflorus* the structure is essentially the same except that the cell-walls of the interior are provided with pores. The intercellular spaces are large. In many of the *Phaseoleae* there are several rows of elongated, palisade-like cells on the superior face. In *Pisum* they are absent from both the inferior and superior faces. In others the cells below are spongy. The spongy structure makes the seed light so that it can easily float (Buchwald 35). Van Tieghem (274. 275) also cites similar cases. In *Astragalus canadensis* the outer row of cells is considerably smaller, the outer walls are thickened, the cells within are much longer with small intercellular spaces. The character and form of these cells are shown in Table G. The microchemical reactions of cell-walls and contents are shown in Table E.

The reserve material varies not only in tribes but in related genera. In general, however, tribes are quite constant. In

Vicieae and *Phaseoleae* the reserve food consists largely of carbohydrates in the form of starch, and proteids in the form of aleurone grains. In *Caesalpinieae* the reserve food occurs in the form of proteids and fat; in *Trifolium*, as starch, proteids and fat; in *Glycine hispida*, largely as fat and proteids; in *Schotia*, *Tamarindus*, and *Lupinus*, as reserve cellulose, proteids and fat. The proteid of leguminous seeds seems to vary greatly. In the pea it is similar to globulin, and is soluble in a two per cent. solution of common salt. The common bean has a proteid known as phaseolin.*

In the Soy bean, the proteids vary from 32 to 44 per cent. (99, 2 : 697). Green (75) has shown that there exists in lupine seed a proteolytic ferment which converts the proteids during germination into pepsin, leucin, and asparagin.

The starch grains are extremely variable, being small in *Trifolium*, relatively large in *Pisum* and *Phaseolus*, and very large in *Rhynchosia erythroides* (Schleiden and Vogel 234), and other species. The starch grains of many of our common species are described and figured in many text-books. Additional facts are given by Nägeli (187), Löhr (150), and Klotz (135). The economic legumes are considered by Harz (99) and Tschirch and Oesterle (267).

Fat, which is commonly present, is embedded in the so-called oil plasma and is an important reserve food. In the Soy bean it varies from 13 to 20 per cent. (Harz 99, 2 : 697).

The cell-walls of some *Leguminosae*, as *Lupinus* sp., *Bianca scandens*, *Centrosema virginianum*, *Clitoria brasiliana*, *C. Mariana*, *Copaifera officinalis*, *Hymenaea Courbaril*, *Swartzia Langsdorfii*, *Goodia*, *Cyanospermum*, *Erythrina ascoca*, and *Tamarindus*, are thickened, in some species more than in others. This reserve material is an amyloid in most cases. Its relation to the thick-walled reserve cellulose is shown in Table E, under endosperm. Two opposite views are held in regard to the reserve nature of this material in *Lupinus albus*. Nadelmann (185) concludes that the cell-walls enter into solution, and his figures show progressive changes. Elfert

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* For a discussion of these products see Griessmayer (77), Osborn & Campbell (194), Green (74), Harz (99, 2), König (136), Jenkins & Winton (125), and a host of chemical writers both American and European.

(61) maintains that the thick-walled cells are not consumed during germination and hence are not of reserve cellulose. This is true, according to Elfert, for *L. luteus*, *L. albus*, and *L. angustifolius*. The same writer, however, refers to the thick-walled cells in the cotyledons of *Impatiens* as reserve material. It is possible that the ferment capable of dissolving the thick walls of cotyledons is similar to Green's (75) amylolytic ferment. Its occurrence and use in *Schotia* were noted by Godfrin (72), but this fact was known to Schleiden and Vogel (234). The facts are brought together by Tschirch (265, 453). Judging from the studies of Harz (99, **2** : 594) and Kumm (138) the cell-walls are generally thickened in the genus *Lupinus*. In our own species studied, the walls are but slightly thickened, usually but little more than in *Phaseolus*.

We may also note the occurrence of chromatophores as well as a nucleus and nucleolus in the cells of cotyledons. The procambial vessels are readily made out in sections treated with chloral hydrate. These cell-walls are not lignified in *Astragalus canadensis*, *Mucuna pruriens*, *Baptisia leucophaea*, *Cassia marylandica*, and *Tamarindus indicus*, nor generally for *Leguminosae* so far as I know. In but few cases has any differentiation taken place in the species that I have studied except *Gymnocladus canadensis* and *Vicia Faba*. According to Klotz (135) spiral tracheids occur in *Pisum*. It may be interesting to observe that in some seeds like *Mucuna* and *Physostigma* a hollow cavity occurs between the two cotyledons. This is to aid dissemination, according to Buchwald (35).

ANATOMICAL CHARACTERS OF SEEDS

From A Systematic Standpoint.

Histological structures of seeds or parts of various drugs have long been brought into requisition as aids for the recognition of plants. This is well shown in numerous works dealing with subjects of pharmacognosy. That anatomical characters of different organs may have a much wider use has also been abundantly shown. Some early attempts were made to use anatomical characters from the standpoint of taxonomy by Fournier (334), 1865, who has given details of structure of different members of the order *Cruciferae*, especially *Sisymbrium*, in which good characters were found. Fournier has published several additional papers on the use of anatomical characters in classification. A. Prunet has reviewed the more important works on anatomy with referference to classification, in Bonnier's Revue Générale de Botanique. Robinson (434a, 137),who has recently studied our North American species of the order, says in regard to *Sisymbrium:* "The pubescence, which, if all species of both continents are considered, passes from simple or occasionally forked hairs to dense stellation, fails to give a really satisfactory generic distinction." Dennert's (384) paper indicates one general type of stem structure and then gives an artificial key based on the presence or absence of hard bast, showing no parallelism between related genera. This order *Cruciferae* is one in which anatomical characters are much used, but not always in a satisfactory way.

The minute structure of the leaves of *Coniferae* has long been used as an aid in the diagnosis of species, as in the works of Engelmann (330), McNab (403–405), Coulter and Rose (318), Penhallow (421) and others. The diagnostic value of anatomical characters has been verified by many students. Duval-Jouve (328), 1870, discussed the anatomical characters of *Gramineae* with special reference to *Agropyron*. His researches show some most striking differences. Hackel, in his monograph on European species of the genus *Festuca*, states that the form of the cross-section of the lamina affords a valuable means for distinguishing some species, though one must cautiously consider variation with reference to soil and climate. Many of our manual species afford valuable anatomical characters, as the work of Mrs. Hansen (418) shows for *Sporobolus*. Holm (381), in a series of valuable papers, describes numerous North American grasses and finds most distinctive characters. Ball (299) has established the same fact for *Eragrostis*, and Miss Sirrine (446), for *Panicum*. It is not necessary to cite further facts in this order.

J. Vesque (458–461) has published several very important papers on the application of anatomy to classification. His researches were not confined to a single order but covered *Anonaceae*, *Berberidaceae*, *Bixaceae*, *Calycanthaceae*, *Canellaceae*, *Capparidaceae*, *Caryophyllaceae*, *Cistaceae*, *Cruciferae*, *Dilleniaceae*, *Frankeniaceae*, *Fouquierieae*, *Magnoliaceae*, *Menispermaceae*, *Papaveraceae*, *Pittosporaceae*, *Polygalaceae*, *Portulacaceae*, *Ranunculaceae*, *Resedaceae*, *Sarraceniaceae*, *Tamaricaceae*, *Tremandraceae*, and *Violaceae*. Various characters are used, such as simple or compound trichomes, presence or absence of crystals, stomata, and fibro-vascular bundles. In a general comprehensive paper on the subject (460. 461) his views have not changed materially, and he adds that taxonomists often fail to obtain all of the material in collections necessary to properly describe a species, hence the descriptions are imperfect. These uncertainties will cease when anatomy occupies a place of merit in the system of classification. This calls to mind the work of Solereder (444), who shows that Masters wrongly determined a *Bragantia* sent to him by Dr. Cleghorn. Solereder states that its anatomical structure shows that it does not belong to the order *Aristolochiaceae* but probably to the *Menispermaceae*. In his exhaustive account of the anatomical characters of this order he includes the structure of the seeds of many species.

The nature of the epidermis, stomata, secretion glands, and sclerenchyma affords valuable diagnostic characters. Radlkofer (429), 1883, emphasized the importance of this application of the anatomy of plants, in his address before the Munich Academy. Pax (420), who has studied the order *Euphorbiaceae*, established an anatomical system. His studies supported the divisions made by Müller instead of the Baillon, and Bentham and Hooker systems. Quite recently, Van Tieghem (457) has made use of some anatomical characters in the special part of his work Éléments de Botanique.

The *Leguminosae* have been investigated by Jaensch (383), Warburg (465), Schube (440), and Van Tieghem (455). Jännicke (384) found eight types of stem in *Papilionaceae*. It was not difficult to find characters of systematic value. In *Vicia* and *Trifolium*, large genera, different characters occur; these are, however, not always so marked as the gross morphological characters. Louis Petit* has published an important monograph (422) on the anatomical characters of the petioles of various orders including representative tribes of the order *Leguminosae.*

Pritzel (428) has recently published a paper of considerable length on anatomical characters, especially in the endosperm of Parietales. According to Pritzel the arrangement of the Parietales is an unnatural one. The *Chlaenaceae* are excluded. Pritzel finds that their anatomical characters show them to be allies of the *Malvaceae* and not *Theaceae*, where the order was placed by Engler and Prantl in their Natürlichen Pflanzenfamilien.

If differential points of this kind occur in related species, what of hybrids? It has been shown that hybrids show intermediate characters. Wettstein (469) has found excellent characters in the hybrids of some conifers, *Pinus* and *Juniperus.* He determined that *J. Kanitzii* had its origin in *J. sabinoides* × *J. communis.* The anatomical structure confirmed his previous opinion.† Intermediate anatomical characters also occur in *Pyrus Malus* × *P. toringo.* If these characters occur and repeat themselves in the hybrid offspring it would certainly seem probable that anatomy should often show some most tangible characters.

This investigation as applied to seeds reveals many excellent characters, shown to better advantage by Harz (99, **2** : 555–1350) than by any other writer. Godfrin (71) was most conservative in expressing the opinion that anatomical seed characters could not be or are of but little value for systematic purposes. I expressed a conservative view in a paper on the structure of the testa in *Euphorbiaceae* (416), to which Gram (339. 340) takes exception. I recognized differences, and

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* The author has a good bibliography and refers to the work of Trécul on the same order, and Acqua, whose work is said to agree with Petit. McAlpine and Renfrey (402) made a careful study of the *Eucalyptus* petiole, in which they found valuable characters. In a later work, 1889, Petit (Nouvelles recherches sur le pétiole des phanérogames. Acts. Soc. Linnéenne de Bordeaux **1889.** Separate, 50, *pl. 1–4*), discusses additional species, including several more *Leguminosae.*

† The Wettstein paper gives some of the literature. Other cases are cited by Kerner-Oliver, Natural History of Plants.

called attention to the mucilaginous spiricles, somewhat similar to those in *Ruellia*, in some sections of the genus *Euphorbia*, and the total absence of mucilage in some species. In some recent studies of the testa of *Berberidaceae*, I have found some excellent generic characters; but very closely related species it is often difficult to differentiate. Subgenera in *Berberis* are easily separated. In *Cruciferae* (417) I have also found some excellent characters. In studies of this kind one is likely to fall into the same errors that the older systematic botanists did, from not having had an abundance of material to work over. Some botanists have drawn inferences from a study of scant material and few species.

In examining the seeds of *Leguminosae*, my studies have been confined to genera and subgenera. Some excellent anatomical characters have been found in tribes and some genera, but it is often difficult to differentiate closely related species. This statement, however, applies equally well to morphological characters. Size is by no means always a good criterion in anatomy, as Schumann (443) has shown, or in taxonomy. The seed is, however, more constant under natural conditions than are the vegetative organs. The general characters of seeds often afford most valuable characters. These have been used in many cases, as in Engelmann's work on *Euphorbia* and numerous other systematic works. Quite recently Cunningham (321) has proposed to use the seed characters of *Plantago*, and Wiegand the same for *Galium*.

SYSTEMATIC.

At first I contemplated only a study of the genera represented in Gray's Manual (6th ed.). As the work progressed, however, it seemed best to include all of our economic genera and a few additional from the South and Southwest.

For synonymy, the Kew Index has been followed, as this agrees essentially with the names applied to the species in Gray's Manual (6th ed.). In the genus *Phaseolus* I have followed Watson. Where these two systems disagree the synonymy is placed in parenthesis. Since Britton and Brown's Illustrated Flora of the United States and Canada is in general use I have placed the names used by them in parenthesis where their system differs from Gray and the Kew Index.

The material for this study was obtained from the herbarium of the Missouri Botanical Garden, the herbarium of the Iowa State College of Agriculture and Mechanic Arts, and the seed collection of the United States Department of Agriculture. I have given a general synopsis of the tribes and genera at the end of the descriptive part of the work.

PAPILIONACEAE — Podalyrieae.

BAPTISIA, Vent.

BAPTISIA LEUCANTHA, Torr. & Gray.

Pl. VII. f. 1. Pl. XXXV. f. 12.

Testa well developed, somewhat irregular on surface, total thickness on sides 398.4 μ.

Malpighian.[*] Cuticle forms a continuous narrow layer, darker in color than the remainder of the cell. The outer portion of the cell-wall separates from the remainder of the wall where the conical projections occur. Light line narrow, occurs underneath the cuticle, and colors blue with chlor-iodide of zinc.

Malpighian cells 117.6 μ. long, somewhat longer toward the hilar region, with a shorter second row. In a surface view the cells are usually six-sided with a central "canal" and 5 to 6 lateral branches; rarely more than two terminal branches. Cell-cavity gradually tapers toward the upper end. The pores extend a little less than one-third of the way down. Pigment and some tannin present; slight lignification below cuticle, and in lower portion of the cell-wall where it joins the osteosclerid.

Osteosclerid. Cells vary in length, mostly 30–80 μ, wider in lower part than above, with large intercellular spaces in the hilar region where the cells are much larger and transformed into star-shaped parenchyma. Cell-walls are colored

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[*] I have employed Malpighian for Malpighian layer, Osteosclerid for osteosclerid layer, Nutrient for nutrient layer, and Mycotic for mycotic layer.

brown, and contain tannin; also a small amount of lignin in the upper part of the wall.

Nutrient. This layer varies in width, and is compressed. On the addition of chloral hydrate four layers of thin-walled cells may be made out, although the number of rows varies in different parts of the section. In the hilar region these number from 12 to 15 and are of lighter color than elsewhere. The lower parts of the layer contain the vascular elements, also thick-walled cells. In the hilar region these cells are thinner walled, and darker in color than in the remaining lower parts of this layer.

Endosperm. This is differentiated into three parts. In the first row or aleurone layer, the cells are thick-walled, nearly isodiametric, filled with granular contents, fat, and albuminoids. Cell-walls mucilaginous and cells contain protein. In the lower portion of the endosperm the cells are elongated and thick-walled, with a narrow cavity.

Embryo. The first row of cells much smaller, forming a compact, continuous layer; cells below larger, except the procambial cells. All of the cells are filled with protein grains and fat. Starch absent. Chloral hydrate causes the fat to come out in the form of globules.— (St. Louis, Eggert, Mo. Bot. Gard.)

THERMOPSIS, R. BR.

THERMOPSIS CAROLINIANA, M. A. Curtis.

Pl. VII. f. 2–2c.

Different layers of testa quite uniformly developed, except in the hilar region. On sides 298.8 μ thick.

Malpighian. Yellowish cuticle uniformly covering these cells, 1.4 μ in thickness; this readily separates from the remainder of the Malpighian cell; the latter is 75.6 μ in length with a rather wide light line extending across the cells underneath the cuticle. Several canals extend into the cell-walls from the surface. Cell-cavity has its greatest width at the lower end, gradually tapering upwards into a narrow line; contains some protein grains, which color brown with chloriodide of zinc. Cell-walls color blue.

Osteosclerid. The cells are quite uniform on sides, 28 μ in length, on ends larger. Cell-walls thickened, with large intercellular spaces. These are much larger at the ends of the seeds. Cell-cavity contains a small amount of protoplasmic matter which colors brown with chlor-iodide of zinc.

Nutrient. This is much compressed, consisting of from three to six layers of cells. Cell-walls mostly thickened; these as well as the contents are brown, owing to the presence of pigment and tannin. Spiral ducts also occur.

Endosperm. This is well developed, especially on the sides, the zone gradually narrows toward the end. First row of cells smaller, thick-walled; contain fat and protein. Followed by two to seven layers of thick-walled cells constituting the reserve cellulose. The cells contain protein and fat. The cell-walls at the lower end are not so thick. A layer of thick-walled, elongated cells with protein matter joins the cotyledons. On the addition of chlor-iodide of zinc the cell-walls of the endosperm color blue.

Embryo. First row of cells continuous, with a large nucleus. Outer cell-walls thicker than the lateral and inner. Remaining cells larger, rather thick-walled, with conspicuous intercellular spaces. All of the cells contain aleurone grains and fat. A few small starch grains occur in the cells below the outer row. — (Buckley, Mo. Bot. Gard.)

THERMOPSIS RHOMBIFOLIA, Richards.

The seeds of the specimen studied were not mature.

Malpighian. Cells variable, longest 95.2 μ in length. Light line runs close under the cuticle and is not strongly marked in specimen.

Osteosclerid. Cells with large intercellular spaces.

Nutrient. Cells nearly coloress, thin-walled and irregular.

Endosperm. Walls of cells but slightly thickened. — (Mont., Mo. Bot. Garden.)

PAPILIONACEAE — Sophoreae.

CLADRASTIS, Raf.

CLADRASTIS TINCTORIA, Raf. (*C. lutea*, Michx., Koch.)
Pl. X. f. 5.

Testa not strongly developed, total thickness on sides 131.6 μ.

Malpighian. Cells 64.4 μ in length. The cuticle forms a continuous layer; light line close under the cuticle; cell-wall between cuticle and light line differentiated into a clearer portion. Cell-walls and cells nearly colorless. Cell-cavity filled with small protein grains which on the addition of chlor-iodide of zinc are colored brown; the cell-wall colors blue. Several canals project into the walls from the cuticularized layer. The Malpighian cells are somewhat elongated in a surface view; canals extend from the central cavity and branch toward the periphery. The branches number from six to seven.

Osteosclerid. Cells as wide above as below, with large intercellular spaces. The cell-walls are thickened and with chlor-iodide of zinc color blue. The contents are granular and color brown with iodine.

Nutrient. Not strongly developed; consists of three or four layers of strongly compressed cells. The cell-walls are not greatly thickened. This layer contains the yellow pigment and the fibro-vascular elements. Not infrequently the layer is differentiated into two parts.

Endosperm. This attains considerable size on the sides of the seeds. It is divided into three parts. In the first or aleurone layer, the cell-walls are greatly thickened; the cells are filled with fat and protein. The aleurone layer uniformly surrounds the remainder of the endosperm. The second portion consists of very thick-walled cells with large pore canals; this varies in width from a few to fifteen cells. The cells contain aleurone grains and fat. On the addition of chloral hydrate the fat collects in drops. The lower part of the endosperm is made up of two or three rows of thick-walled cells, much longer than broad, containing protein grains. The cell-walls of the endosperm color blue with chlor-iodide of zinc; contents color brown with iodine.

Embryo. The first row of cells forms a continuous layer. The outer cell-walls are more strongly thickened than the lateral. The remaining cells are thinner-walled and much larger, irregular, with intercellular spaces. The cells are filled with aleurone grains and fat, but no starch. Iodine colors the aleurone grains brown; the cell-walls are colored blue with chlor-iodide of zinc.

SOPHORA, L.

SOPHORA SERICEA, Nutt.

Pl. X. f. 1–1c.

Testa developed quite uniformly. The testa with endosperm measures 196.4 μ in thickness, but on the sides of the seed, 243 μ; near the ends of the seed, only 64.8 μ.

Malpighian. The cuticle forms a continuous thin layer; the narrow light line runs close under the cuticle just below the cuticularized layer. The cavity is large at the lower end, gradually tapering upward. Several canals project into the thickened cell-wall; these are of different lengths. With chlor-iodide of zinc the cuticularized layer colors darker blue than the remainder of the cell-wall, corresponding to the structure found by Schips for some other leguminous seeds.

Osteosclerid. Cells are thick-walled, with large intercellular spaces, quite uniform as to size. Walls slightly brownish in color, and coloring blue with chlor-iodide of zinc.

Nutrient. The cells are much compressed, rather thick-walled, and vary somewhat in size. Cells of the lower portion are smaller than in the upper. This layer contains the brown pigment and the vascular elements. The walls color blue with chlor-iodide of zinc.

Endosperm. This is well developed and is differentiated into three parts: (1) aleurone layer, (2) reserve cellulose, (3) narrow, elongated, thick-walled cells. Cells of the aleurone layer are uniform throughout and surround the entire reserve cellulose. The cells contain fat and protein grains. The cell-walls in part consist of reserve cellulose which is mucilaginous. Cell-walls are thickened and provided with large pore-canals. The cell-cavity contains protein. In the layer next to the cotyledons the walls are thickened and elongated; the cells are small and contain some protein matter. On the addition of chlor-iodide of zinc the outer portion of the cell-wall immediately colors blue. The inner portion of the cell-wall takes a lighter shade of blue.

Embryo. The first row of cells forms a continuous row; the outer wall is thickened. The cell-walls below the outer row have minute canals. The cells contain protein, fat, and minute starch grains. The cell-walls consist of cellulose.

PAPILIONACEAE — Genisteae.

CROTALARIA, Dill.

CROTALARIA SAGITTALIS, L.

Pl. X. f. 4.

The testa not strongly developed; endosperm 196 μ in thickness. From Nadelmann's studies it appears that in *Crotalaria verrucosa* the horny endosperm is well developed, being four and one-half times as wide as the testa. The aleurone layer contains fat and aleurone grains. The cells of the embryo contain protein and fat but no starch.

Malpighian. The cells are prismatic in surface view, 9.8 μ across, with five to six canals. In cross-sections they are 84 μ long. The cuticle forms a continuous layer; with longitudinal canals projecting into the cells; these extend down through the upper part of the cell-wall and the cuticularized substance; this layer is lighter in color than the rest of the cell-wall, and separates from the remainder of the cell in the form of a band. The narrow light line occurs close under the cuticularized layer. The cell-cavity is narrow and gradually tapers upward; it contains some protein matter. The cell-wall consists of cellulose.

Osteosclerid. The walls are thickened. Cells wide in the lower part and narrowing upwards, with large intercellular spaces. Cells contain protein.

Nutrient. Consists of radially elongated cells, which are slightly compressed. Walls of medium thickness, slightly colored.

Endosperm. Not strongly developed. The cells of the aleurone layer large, containing protein. Two layers follow this, the cells very much compressed, and somewhat radially elongated. The lower portion radially elongated, of thick-walled cells. All of the cells contain protein and fat.

Embryo. Cells of outer row smaller; those adjoining the endosperm thicker-walled, the inner part with thinner walls. The remaining cells of the embryo larger. All of the cells filled with protein. Starch is absent.

GENISTA, L.

Detailed studies of the anatomy of the seeds have been made by Nadelmann and Harz, and brief notes by Tschirch. Schleiden and Vogel long ago pointed out that "Dyer's Green Weed" is albuminous. On the addition of water the horny endosperm becomes mucilaginous. The cell-walls are greatly thickened. Schleiden and Vogel as well as Nadelmann and Harz speak of a green pigment found in the Malpighian cells, to which the name of "Seladon green" has been given.

GENISTA TINCTORIA, L.

Pl. X. f. 2–2c.

Total thickness of testa including endosperm 332 μ; strongest development on the sides.

Malpighian. Cells forming a continuous layer but in sections frequently showing rifts; uniformly developed, 56 μ in length and wide in proportion to their length; cell-cavity conspicuously wider at the lower end then gradually tapering upward; several canals projecting into the cell-wall; light line under the cuticularized portion, narrow but very bright.

Osteosclerid. Cells short, thick-walled, nearly of equal width except the constriction in the middle, which results in a large intercellular space between the contiguous cells; slightly colored and somewhat compressed.

Nutrient. Layer somewhat compressed, more conspicuous than the osteosclerid layer; walls colored greenish, containing protein grains and coloring matter.

Endosperm. Width varying in different parts of the seed but attaining its maximum development on the sides between caulicle and the chalazal region, and measuring 132.4 μ. Aleurone cells thick-walled and conspicuously different from the remainder of the endosperm (stated by Nadelmann not to be different). Cells containing fat and protein grains. The horny endosperm on the addition of water becoming mucilaginous. Cells with well-developed pore-canals and the cell-walls differentiated into two parts. On the addition of chlor-iodide of zinc, the primary cell-wall colors blue rather slowly.

The inner colors blue more rapidly. Protein grains are abundant in cavity. The lower portion of the endosperm consists of elongated, thick-walled cells; this layer surrounds the whole embryo.

Embryo. First row of cells much smaller than those within, nearly isodiametric, outer walls thickened; the lateral thin-walled, apparently striated, with longitudinal bars. Several rows of palisade cells on superior face of cotyledon. Cells packed with fat and protein grains. Walls color blue with chlor-iodide of zinc. Starch is absent.

LABURNUM, L.

LABURNUM ANAGYROIDES, Medic.

For allied species see *Cytisus scoparius*. — *Pl. X. f. 3.*

According to Nadelmann the structure of *Cytisus Laburnum* approaches that of *Tetragonolobus purpureus.* The Malpighian cells carry a green pigment; the endosperm reaches its greatest development laterally. The tertiary membrane of the reserve cellulose in the endosperm colors blue. The seeds of Scotch Broom were formerly considered medicinal. Husemann and Marmé isolated a very poisonous, strongly basic alkaloid, cytisin.

Testa and endosperm measure 431.6 μ in thickness, the endosperm being more than twice as thick as the testa. The testa differs little from that of *Genista tinctoria.*

Malpighian. Cuticle forms a continuous layer and in mounted specimens shows fissures; light line is a narrow zone close under the cuticle. Cell-cavity wide at lower end, gradually tapering upward. Canals extend down into the cell-wall for more than one-third of the distance.

Nutrient. This layer is moderately developed, consisting of four rows of irregular, thin-walled cells, containing some protein grains.

Endosperm. The first layer of cells, the aleurone, with thick walls, containing protein grains and fat; the remainder of the endosperm, except the portion next to the embryo, consists of thick-walled cells with pore-canals; these contain some fat and protein grains.

Lupinus, Tourn. L.

The seeds of the genus *Lupinus* have long been subjects of study. Malpighi described the seeds of Lupinus as follows: "Eadem ferè configuratio occurrit in pisis & lupinis 302, quorum secundina exterior solitis fistulis A componitur, horizontaliter ductis, quibus multiplices substant ordines utriculorum B, vario situ & figurâ constantes, hisque contento semini cellula paratur." Later studies were made by Schleiden and Vogel, who found a small amount of endosperm present in the seeds of *L. tomentosus*, DC., and *L. polyphyllus*, Lind. (*L. macrophyllus*, Benth.). Endosperm, according to Harz, is absent in most of the species, although found in small quantity in *L. hirsutus*, L. and *L. angustifolius*, L. Sempolowski found that in the last species it consists of a single row of strongly compressed cells which on the addition of water become mucilaginous. Nadelmann states that *L. polyphyllus*, Lind., and *L. luteus*, L., have a small amount of endosperm while all the others studied by him are without endosperm. In *Leguminosae* the reserve cellulose is, as a rule, found in the endosperm but in several species of *Lupinus* it occurs in the cotyledons where it is an amyloid. In germination these secondary cell-walls become soluble, the primary wall remaining. Nadelmann has studied the process in detail and concludes that the secondary thickening of walls in cotyledons constitutes reserve material. The loss of this substance in cotyledons is progressive with the appearance of starch and chlorophyll. The seeds of lupines are highly nitrogenous, containing as much as 42.21 per cent. of albuminoids. These albuminoids in lupine seeds have been called conglutin by Ritthausen. The cellulose is said to occur in two forms by Siewert, useful and useless so far as the food of the plant is concerned. In cotyledons and seed coats 11.45 per cent. is of the useful, and 13.24 per cent. of the useless. Seeds of lupines contain a bitter alkaloid known as lupinin which is readily soluble in cold water. Several insoluble alkaloids also occur; among these, perhaps, small quantities of coniin. In different species the alkaloids vary from 0.02 to 1.0 per cent.

LUPINUS PUSILLUS, Pursh.

Pl. IX. f. 1–2.

The testa and endosperm of this species measure 124.5 μ. The Malpighian cells and the osteosclerids are well and uniformly developed.

Malpighian. Cuticle forms a continuous well-developed layer; cells 49.80 μ long; a broad light line occurs close under the cuticularized layer. This layer colors blue with chloriodide of zinc. The cell-cavity is large at the lower end with wavy margins, and contains small protein grains.

Osteosclerid. The cells have thick walls and a narrow cavity, as wide above as below, and a constriction in the middle with a large intercellular space between the cells.

Nutrient. This layer is but slightly developed; cell-walls thin, and the cell-cavity contains granular contents; it contains the vascular elements.

Endosperm. In the seed studied, which was not quite mature, development had progressed far enough to show thick-walled cells such as usually occur in the lower part of the endosperm next to the cotyledons.

Embryo. Cells of first row with greatly thickened exterior cell-walls; lateral walls thinner; the remaining cells with thinner walls, irregular, with intercellular spaces. Palisade cells of superior face consist of three to four rows. Cells rich in protein which is contained in the oil plasma. Starch is absent. — (Wyoming, Nelson, Mo. Bot. Gard.)

LUPINUS ALBUS, L.

Pl. IX. f. 3.

Testa strongly developed, 415 μ thick. The pigment layer is much more conspicuous than in *L. pusillus.*

Malpighian. Cells are 140 μ long. The cuticle forms a continuous, somewhat irregular layer; broad light line below the cuticle. Several light lines have been distinguished in this species. Numerous canals project into the cell-wall; cavities irregular, very narrow, containing granular contents. Below the middle the wall shows a deflection, hence appearing somewhat geniculate.

Osteosclerid. Layer strongly developed; thick walls with a constriction in the middle; large intercellular spaces between the cells. Upper and lower bars equal.

Nutrient. Cells thin-walled, irregular, of a yellow color; lower part of the layer is much compressed and the cell-walls contain more pigment. The layer also contains the vascular elements.

Endosperm. Though the statement is made that the seed of this species is without endosperm, it has the same amount as *L. pusillus.* The cells are elongated, thick-walled, containing protein grains.

Embryo. The cell-walls thickened, consisting of reserve cellulose. Starch absent. Cells contain fat and protein.

PAPILIONACEAE — Trifolieae.

The tribe *Trifolieae* is represented by three genera in the Manual, only one of which is indigenous, *Trifolium.* Most of the species of this genus are introduced. An anatomical study of the seed gives additional reason for maintaining this as a distinct tribe. The cotyledons contain small starch grains and most of the species are provided with endosperm. The osteosclerids, so far as they have been studied, are longitudinally striated in all of the genera examined, *Trifolium*, *Ononis*, *Trigonella*, *Medicago*, and *Melilotus.* The African and Asiatic *Parochetus* has not been examined. The walls are not longitudinally striated in the related *Lotus* and *Tetragonolobus.*

TRIFOLIUM, Tourn.

There are several excellent accounts of the structure of the seed, by Sempolowski, Harz, and Nadelmann. My studies are inserted here so that the species may be compared with others. Endosperm is well developed but variable in thickness. Walls of the testa and endosperm 91 μ to 140 μ in thickness.

TRIFOLIUM PRATENSE, L.

Pl. IX. f. 6–6b.

Malpighian. Cells are 56 μ long. Surface view of the cells prismatic; pore-canals extending from the center; the cuticle forms a continuous even layer, darker in color than the cuticularized layer. In cross-section several canals may be seen extending into the cell-walls from the cuticle. A narrow light line runs close under the cuticularized layer. The cell-cavity gradually tapers upward and is filled with protein grains, tannin, occasionally a large chromatophore, and pigment. The cell-walls color blue with chlor-iodide of zinc.

Osteosclerid. Layer is well developed; cells uniform in width above and below, as a rule with but a slight constriction in the middle, 12.6 μ to 14 μ in length and 11.2 μ in width. Cell-walls greatly thickened and provided with longitudinal canals. In sectional view these plainly indicate that they are minute canals, and not folds as has been stated by some writers.

Nutrient. The layer is unequally developed, from a few rows of cells to a dozen; the cells are thin-walled, somewhat elongated, compressed, walls colored greenish or purplish.

Endosperm. The cells of the aleurone layer are longer than broad, thick-walled, containing fat and protein grains. In the underlying cells the primary cell-wall is thin, the remainder of the cell-wall constitutes the reserve cellulose and is greatly thickened. Following this is a layer consisting of one or two rows of elongated, thick-walled cells.

Embryo. The first cells of the first row are smaller; cell-walls which join the endosperm are thickened; the remaining cells are larger except the procambial vessels. All of the cells contain an abundance of protein, small starch grains, and fat. Cell-walls color blue with chlor-iodide of zinc. — (St. Louis, L. H. Pammel.)

TRIFOLIUM REFLEXUM, L.

Pl. IX. f. 5.

Testa and endosperm 100–110 μ in thickness. The Malpighian cells nearly as long as endosperm and remainder of testa are thick.

Malpighian. Quite uniformly developed, 42–44 μ in length. Cuticle thickened irregularly; cuticle and cuticularized part separating readily from the remainder of the cells; the light line rather wide under the cuticularized layer; several canals projecting into the cell-wall; cells containing protein grains and pigment, and a conspicuous large chromatophore in their lower part.

Osteosclerid. Cells with a broad base and hence a triangular space under the Malpighian cells; cell-walls thickened, and marked with longitudinal striae, the canals. The cells contain some protein grains.

Nutrient. Layer but slightly developed. Parenchyma cells contain pigment, the cell-walls also pigmented.

Endosperm. Aleurone layer of elongated, thick-walled cells, containing fat and protein, followed by one or more layers of larger cells with similar walls, and, in the lower part, by thick-walled, elongated cells with a narrow cavity. These cells contain some protein grains.

Embryo. First row of cells smaller; the outer walls next to the endosperm thickened. These cells have an abundance of protein and fat but no starch. The remaining cells are as in *T. pratense*, but with less starch. — (Shannon Co., Mo., B. F. Bush, Mo. Bot. Gard.)

TRIFOLIUM AGRARIUM, L.

Pl. IX. f. 2b.

Testa and endosperm 60–90 μ in thickness. In the narrow portions the Malpighian cells are nearly as long as the remainder of the testa is thick. The endosperm much the same as in *T. reflexum* except that the round chromatophores are near the center and the intercellular space between the osteosclerids is smaller. The cell-walls of the aleurone layer are thicker. The mucilaginous reserve cellulose of the endosperm is thick-walled. The cells of the embryo as in other species; numerous small starch grains and aleurone grains. The walls of the outer row of cells greatly thickened. — (Nantucket, Mass., Fritchey).

MELILOTUS, Tourn.

The species of this genus are much alike and in their anatomical structure resemble *Medicago*. The osteosclerids have conspicuous longitudinal canals. The aleurone layer is well-marked, and there are variable amounts of additional endosperm. The testa and cotyledons contain cumarin which also occurs in other genera, as in Tonka bean, and in *Hierochloe*, a grass.

MELILOTUS ALBA, Lam.

Pl. VIII. f. 2.

Testa and endosperm vary in thickness, average 75 μ. Malpighian cells as long as the thickness of the endosperm and remainder of testa.

Malpighian. Cuticle wavy and well developed; the cuticularized layer below with small, conical projections, those of two adjoining cells meeting at the middle lamella of the lateral walls, giving the layer the appearance of consisting of cone-like projections. These cones are also connected with the small pore-canals. This cuticularized layer is highly refractive. The light line consists of a narrow but distinct refractive zone below the conical layer. The refractive zone colors blue with chlor-iodide of zinc. The whole upper part is, however, more or less refractive. The remainder of the cell-wall contains pigment and is colored blue with chlor-iodide of zinc; the cuticularized layer as well as the conical layer colors blue. Small canals project into the walls, in some cases extending beyond the light line. The chromatophores are irregularly distributed in the cell-cavity, some near the base, others in the center.

Osteosclerid. Cells with a broad base and a small triangular intercellular space above; longitudinal pore-canals in the upper part of the cell, but these do not extend its entire length.

Nutrient. This layer is much compressed; consists of thin-walled cells, divided into two parts; cell-walls of lower part thicker. Both layers contain pigment and tannin, the upper more than the lower. Cell-walls consist of cellulose.

Endosperm. The aleurone layer is quite distinct; the cells are rectangular; cell-walls made up of cellulose. The walls of the remainder of the endosperm, except where it joins the embryo, are thick, consisting of mucilaginous reserve cellulose. Cells of the internal layer of the endosperm thick-walled, elongated, containing some protein grains and fat.

Embryo. Cells of the exterior walls of first row thickened; they are smaller than those below. All of the cells contain fat, protein grains, and small starch grains. Procambial vessels well developed.—(St. Louis, Eggert, Mo. Bot. Gard.)

MELILOTUS OFFICINALIS, Lam.

Pl. VIII. f. 1–1c. 5.

Testa with endosperm varying from 260 to 300 μ in thickness. The Malpighian cells of this species are longer than in *M. alba*, and also more abundantly supplied with pigment. The conical projections are longer. The osteosclerids are longer and nearly as wide above as below. The longitudinal canals as conspicuous and well-developed as in that species. Cells of the nutrient layer, especially in the lower part, are abundantly supplied with pigment and some tannin. The walls of the aleurone cells are thick; the mucilaginous reserve cellulose and the thick-walled, elongated cells are not essentially different from the last species. It also agrees with it with respect to the embryo. — (Europe, Reverch., Mo. Bot. Gard.)

MEDICAGO, Tourn.

The seeds of several species have been studied by Harz, Sempolowski and Nadelmann. The Malpighian cells are provided with conical projections as in *Melilotus*. The walls of the osteosclerids are longitudinally striated; the aleurone layer is very different from the mucilaginous endosperm. The species are not exalbuminous as stated by Lubbock. The seeds, especially of *M. sativa*, are variously colored. Haberlandt, according to Harz, has determined that the lighter colored seeds germinate more rapidly and better than the dark-colored ones.

MEDICAGO SATIVA, L.

Pl. XXIV. f. 1-1h.

Testa uniform in thickness; endosperm variable.

Malpighian. Cells are 39–42 μ long. Cuticule forms a continuous surface; cuticularized layer with conical projections, conspicuous. With chlor-iodide of zinc it colors blue; the cuticle, brown. The light line occurs below the cuticularized layer; this colors light blue with the same reagent. The remainder of the cell-wall colors dark blue. The cell-cavity is large at the base, gradually tapering upward, small in the upper part of the cell. Several pores in each cell project into the wall beyond the light line. Normally the cells as a whole are colored yellow, and contain tannin and some yellow pigment.

Osteosclerid. Cells usually have a broad base and an intercellular space in the upper part of the layer. Cells in sections from the lateral part of seed are more or less I-shaped with the base somewhat broader, longitudinally striated. Cell-walls are colorless and with chlor-iodide of zinc color blue. Some tannin present in the cell-cavity.

Nutrient. This layer is differentiated into two parts, and is much compressed. Cells elongated, thin-walled; Cells in the lower part are smaller and contain much more pigment and tannin than those of upper portion. Walls color blue with chlor-iodide of zinc. Vascular elements occur in this layer; these give the lignin reaction. Parenchyma cells surrounding the root cap also give reaction for lignin.

Endosperm. Aleurone cells very distinct; containing fat and protein. The thick walls consist of reserve cellulose; walls color but faintly with sulphuric acid and iodine; the non-mucilaginous cells below are elongated, thick-walled, with a small cavity in which some protein remnants occur. In water the walls become mucilaginous, and change in outline. Internal layer of endosperm of several rows of thick-walled, elongated cells.

Embryo. The cells of the first row are smaller, with thick exterior walls which color blue with chlor-iodide of zinc. The cells below are larger and somewhat irregular; the portion of the cotyledon next to the endosperm becomes the under side when the seed germinates; the cells of the interior rows where the cotyledons meet, except the outer, are elongated, palisade-like, and become true palisade cells in germination, composing two or more rows which are closely connected with the procambial vessels. Cells of the cotyledons densely filled with protein and fat.

Iodine alone does not show starch grains because obscured by fat and protein. When treated with chlor-iodide of zinc small round or elliptical starch grains show.— (S. W. Texas, Heller, Mo. Bot. Gard.)

MEDICAGO LUPULINA, L.

Pl. VIII. f. 3–3b. Pl. XXIV. f. 2–2b.

Testa and endosperm well developed, 245 μ in thickness on sides. More than half of this thickness consists of endosperm.

Malpighian. Cells 40–42 μ in length. Cuticle slightly irregular; underneath the cuticle a light-colored area with conical projections, as in *Melilotus*, but somewhat more prominent. With chlor-iodide of zinc this rapidly colors blue. It corresponds to the mucilaginous "membrana interna" of Mattirolo and Buscalioni, and, as shown by Schips, is chemically differentiated from the cuticle and remainder of the cell-wall. The conical layer is highly refractive. The light line occurs below the conical layer and colors blue soon after the addition of chlor-iodide of zinc. The cell-cavity is broadest at the base, gradually tapering upward. A large chromatophore occurs at the base or near the middle of the cell-cavity. In colored seed some pigment occurs in the cavity as well as considerable amounts in the walls. Small pore-canals occur in the upper part of the cell-wall. The cell-walls color blue more slowly with chlor-iodide of zinc than the cuticularized layer.

Osteosclerid. Cells broad at the base, with conspicuous longitudinal pores; intercellular spaces below the Malpighian cells triangular; walls colored brownish; cells containing pigment and tannin.

Nutrient. This layer is much compressed, and differentiated into two parts; cells elongated, rather thin-walled; those in the lower portion carry a great deal of pigment, and are much more compressed that the upper portion.

Endosperm. The endosperm is of unequal development, laterally as much as 150 μ in thickness. Harz gives the thickness as 250 μ. Cells of the aleurone layer rectangular, thick-walled, and filled with fat and protein grains. This layer is followed by reserve cellulose. The primary wall persists when treated with weak solvents. The walls, except the primary, color blue with chlor-iodide of zinc. The inner portion of the endosperm consists of thick-walled, elongated cells.

Embryo. Cells of the first row smaller than those below; exterior walls thickened more than the lateral; all of the cell-walls consist of cellulose. Cells contain fat and protein grains; starch grains do not occur, though Harz says they are usually abundant. In several specimens examined I was unable to find starch, neither when potassium hydrate nor weak sulphuric acid was used with the iodine. — (Fritchey, Craighead, Penn., Mo. Bot. Gard.)

MEDICAGO DENTICULATA, Willd.
Pl. VIII. f. 4–4b.

The seeds of this species agree with those of *M. lupulina.*

Malpighian cells 35–38 μ long; the narrow light line occurs below the conical layer; the chromatophores are absent.

Osteosclerids 16–18 μ long; longitudinal striae well marked. Cross sections show beyond a doubt that these striae are canals. The nutrient layer is much compressed.

Aleurone layer of endosperm as in *M. lupulina.* The mucilaginous reserve cellulose not so strongly developed as in the last species. Treatment with iodine gives no reaction for starch; nor do blue grains appear when treated with weak sulphuric acid and iodine, or potash and iodine. An abundance of fat and protein grains occur in the cells. Walls of the reserve cellulose color light blue. Malpighian cells a darker blue. — (Todaro, Palermo, Herb. Curling-Joad, Mo. Bot. Gard.)

PAPILIONACEAE — Loteae.

HOSACKIA, Dougl. (*Lotus*, L.)

Anatomically the seed of this genus is very distinct from *Medicago*, *Trifolium*, *Melilotus*, and *Ononis.* It shows considerable affinity to *Lotus* and *Tetragonolobus.*

HOSACKIA PURSHIANA, Benth. (*Lotus americanus*, Nutt., Bisch.)
Pl. XI. f. 5–5b.

Testa conspicuously brown-colored, uniform. Endosperm somewhat variable in thickness. Endosperm and testa 180 μ in thickness.

Malpighian. Cuticle strongly developed; outer surface roughened; followed by a rather wide cuticularized layer. Conical layer not very evident. Narrow light line immediately below the cuticularized portion. Cell-cavity large at the base, and terminating rather abruptly. Cell-walls and contents brown in color; cells containing tannin. The walls color blue with chlor-iodide of zinc.

Osteosclerid. Cells short, as wide above as below; I-shaped, prominently constricted. Longitudinal striae of walls not evident.

Nutrient. Layer differentiated into two parts, the upper more compressed than the lower; cells thin-walled, the walls deeply colored.

Endosperm. Cells of the aleurone layer thick-walled, in outline more or less quadrangular; containing fat and protein grains. The mucilaginous reserve cellulose layer follows; this is of variable thickness and agrees with *Lotus corniculatus.* The conspicuous pore-canals connect with adjoining cells. The internal part of the endosperm is more or less compressed and consists of thick-walled, elongated cells; the narrow lumen contains proteid substances.

Embryo. The exterior walls of the first row of cells are thicker than the lateral. This layer forms a continuous row of nearly isodiametric cells. The cells below are somewhat irregular, with intercellular spaces in the angles. Superior face with two rows of palisade cells. Cells contain fat and protein grains but no starch. — (Oklahoma, Waugh, Mo. Bot. Gard.)

PAPILIONACEAE — Galegeae.

PSORALEA, L.

The Malpighian cells are well developed. Conical layer absent. Osteosclerids thick-walled, non-striated; endosperm but sparingly developed.

PSORALEA MELILOTOIDES, Michx. (*P. pedunculata*, Mill., Vail.)

Pl. XI. f. 4–4c.

Testa and endosperm of variable thickness, 160–200 μ, most of this variation being found in the testa.

Malpighian. Cuticle thick, slightly irregular; sections show rifts due to the collapse of the mucilaginous cuticularized layer. The narrow light line forms a distinct zone below the cuticularized portion; both color blue with chlor-iodide of zinc soon after the addition of the reagent. Pore-canals elongated, extending nearly to the lower part of the cell. Cell-cavity small, containing a brown pigment, the walls colored in the same way.

Osteosclerid. The thick-walled cells are elongated; upper and lower bars nearly equal; cell-cavity small; intercellular spaces elongated. Cells contain protein grains and pigment.

Nutrient. Layer unequally developed; cells are elongated, and loosely arranged. Pigment abundant in the lower part of layer; the vascular elements also occur in this portion. The walls color blue with chlor-iodide of zinc.

Endosperm. Sparingly developed. Aleurone cells somewhat elongated, containing fat and protein grains; this layer is followed by the mucilaginous reserve cellulose, consisting of large cells. Internal part of endosperm consists of thick-walled, elongated cells, containing protein grains and fat.

Embryo. Exterior walls of the first row of cells are thickened. The cells, which are smaller than those below, form a continuous row. The interior cells are more loosely arranged. The superior face consists of three to four rows of palisade cells. The cells contain fat, protein, and small starch grains. Cell-walls color blue with chlor-iodide of zinc. — (N. W. B., Mo. Bot. Gard.)

PSORALEA TENUIFLORA, Pursh.

Pl. XI. f. 1–1b.

Testa well developed, 260–275 μ in thickness. The species characterized by a conspicuous mycotic layer; endosperm nearly wanting.

Malpighian. Cuticle forms a thick, even layer; the well-marked light line occurs close under the cuticle; numerous pores project into the nearly colorless wall. Cell-cavity irregular, constricted, containing one or more chromatophores of different sizes, protein, and but a small amount of pigment.

Osteosclerid. Cell-walls greatly thickened; upper and lower bars wide, 30–35 μ; constriction 20–25 μ. Cells contain protein grains, pigment, and tannin, and in color contrast decidedly with the Malpighian layer.

Nutrient. The cells of this layer are thick-walled, elongated, and brown, containing protein grains and tannin. It also contains the vascular elements.

Mycotic. This layer is of considerable thickness, measuring 56 μ; the cells are nearly colorless, thick-walled, and elongated; the elongated, tortuous cells are partially separated by numerous small intercellular spaces.

Nucellus. Although the development has not been studied, I believe that the layer below the mycotic is the nucellus. The cells are very dark in color — much more so than the usual nutrient layer or nucellus.

Embryo. The outer row of cells continuous; no intercellular spaces; exterior walls thickened; much smaller (14–16 × 9.8–14 μ) than the parenchyma below; these measure 33.6–56 × 33–19.6 μ. Cells contain fat and protein grains but no starch.

PSORALEA CUSPIDATA, Pursh.

Pl. XI. f. 2–2b.

Testa and small layer of endosperm 99.6–23.4 μ in thickness, nearly colorless, as in *P. tenuiflora.* Osteosclerids also agree with those of that species. The nutrient layer with a great deal of pigment. Endosperm sparingly developed. First row of cells of embryo somewhat elongated, with thin lateral walls; exterior walls thicker. Interior cells of embryo thin-walled, with a triangular intercellular space at the angles. — (Kerrville, Texas, Heller, Mo. Bot. Gard.)

AMORPHA, L.

Schleiden and Vogel called attention to the mucilaginous endosperm of this genus. The species here studied mostly agree as to their Malpighian cells. The endosperm is unequally developed.

AMORPHA CANESCENS, Nutt.

Pl. XI. f. 3–3b.

Testa and endosperm vary in thickness, 95–232 μ, mostly due to the endosperm, which reaches its greatest development on the sides at the two ends.

Malpighian. Cells are 58–62 μ in length. Cuticle is uniform in thickness, well-developed; cuticularized layer not conspicuous, but on the addition of chlor-iodide of zinc it colors a faint blue; the light line occurs underneath the cuticularized layer and colors blue on the addition of the same reagent, as does the remainder of the cell-wall, though less promptly. From this and other species it is evident that the light line contains less foreign matter than the remainder of the cell-wall. The cell-cavity is broad and irregular at the lower end but gradually tapers upward. It contains protein grains, pigment, and tannin.

Osteosclerid. Cells are elongated, thick-walled; the cross bars somewhat unequal; upper portion smaller; large intercellular spaces between the cells.

Nutrient. This layer is differentiated into two parts. Walls are not greatly thickened, and color blue with chlor-iodide of zinc. The lower part of the layer takes on a deeper color than the upper. Contents and walls color brown with the same reagent.

Endosperm. Varies in thickness. Aleurone cells thick-walled. The reserve cellulose cells are thick-walled, and become mucilaginous on the addition of water. The walls color blue with chlor-iodide of zinc. The primary cell-wall is thin. The compressed internal layer consists of thick-walled, elongated cells with a small lumen. The reserve cellulose cells and internal layer contain fat and protein.

Embryo. The exterior walls of the first row of cells are thickened. The internal cells are smaller and thinner-walled than those of the outer row. The walls color blue with chlor-iodide of zinc. Cells contain fat, protein, and small starch grains. — (St. Louis, Eggert, Mo. Bot. Gard.)

AMORPHA FRUTICOSA, L.

Pl. XI. f. 6–6b.

This species was studied by Schleiden and Vogel, who reported the presence of endosperm. It does not differ essentially from *A. canescens.* Testa and endosperm 150–335 μ in thickness, this variation largely due to the endosperm. Malpighian cells 66.4 μ long; pore-canals well marked. Chlor-iodide of zinc colors the cell-walls blue very rapidly. Osteosclerids variable as to length, thick-walled, with large intercellular spaces. Cells contain pigment, tannin, and protein. Nutrient layer as in the last species. Cells of the aleurone layer of the endosperm are thick-walled. Cells of the reserve cellulose with small pore-canals. Walls differentiated into three distinct layers. The secondary wall colors blue rapidly, the inner is more refractive and colors violet blue. The cells contain fat and protein. The internal layer of the endosperm as in *A. canescens.* The cells of the embryo agree with those of the last species as to structure, but starch was not found. — (N. C., Mo. Bot. Gard.)

DALEA, L. (*Parosela*, Cav.)

Early studies of some species of this genus were made by Schleiden and Vogel. All of the species, thus far studied, contain endosperm. The embryo contains no starch. Pigment abundant in the nutrient layer.

DALEA ALOPECUROIDES, Willd. (*Parosela Dalea*, L., Britt.) *Pl. XII. f. 1–1b. 5.*

Testa and endosperm from 150–265 μ in thickness. Variation is mostly due to the endosperm, which reaches its greatest development laterally.

Malpighian. Cells are 36.4 μ in length. Cuticle prominent; cuticularized layer not conspicuous; narrow light line near the cuticle; pores prominent, extending into the walls beyond the light line. Cell cavity broad at the base, containing protein grains.

Osteosclerid. Cells thick-walled, lighter in color than the Malpighian layer. They contain pigment, tannin, and protein.

Nutrient. This layer is compressed and the cells are elongated. Walls color blue with chlor-iodide of zinc. Brown pigment abundant in the vascular region.

Endosperm. Aleurone cells nearly isodiametric, containing fat and protein; most of the endosperm consisting of reserve cellulose, with prominent pore-canals; the internal layer consisting of elongated, thick-walled cells, with cell-cavity much reduced.

Embryo. First row of cells of embryo smaller than underlying, with thickened outer walls. Cells below with small intercellular spaces. Reserve material consists of fat and protein grains; starch is absent. — (Iowa City, Iowa, Hitchcock, Mo. Bot. Gard.)

DALEA LAXIFLORA, Pursh. (*Parosela enneandra*, Nutt., Britt.) *Pl. XII. f. 7.*

Structurally much as in the last species. Testa and endosperm 130–180 μ in thickness. Malpighian cells 42 μ long; nearly colorless, with a large chromatophore in the cell-cavity; several conspicuous pore-canals extend from the surface, somewhat beyond the light line. Osteosclerids are thick-walled and wide at the base; the intercellular space larger above than below. Nutrient layer as in the last species. The aleurone cells of endosperm thick-walled; the remainder, except the internal layer, consists of mucilaginous reserve cellulose. Embryo as in *D. alopecuroides.*

PETALOSTEMON, Michx. (*Kuhnistera*, Lam.)

Seeds with endosperm. Malpighian cells yellowish, with a large cavity and chromatophores.

PETALOSTEMON CANDIDUS, Michx. (*K. candida*, Willd., Kze.) *Pl. XII. f. 6–6b. Pl. XXVIII. f. 4–4c.*

Testa and endosperm 90–110 μ in thickness, the latter variable, but strongly developed laterally.

Malpighian. Cells are 33 μ long. Cuticle forms an even and continuous layer; the cuticularized layer follows; light line occurs under a narrow and distinct zone of the latter; pore-canals project into the walls somewhat below the light line but are indistinct. Cell-cavity wide at the base and gradually tapering upward; the large chromatophore colors brown with iodine. Cell-walls color blue with chlor-iodide of zinc; the light line pale blue with the same reagent. The cuticularized layer readily separates above the light line.

Osteosclerid. Cells are elongated, with long intercellular spaces; the walls are greatly thickened and color blue with chlor-iodide of zinc; the contents color brown.

Nutrient. In seed not quite mature this layer consists of five to ten rows of thin-walled cells containing an abundance of pigment and tannin. Chlor-iodide of zinc colors the walls blue; the vascular elements are lignified.

Endosperm. The first layer of cells, aleurone, thick-walled, followed by a variable amount of mucilaginous reserve cellulose. Cells in lower part are thick-walled and elongated; the reserve cellulose readily dissolves in mineral acids. Contents color brown with iodine, and the walls, blue with chlor-iodide of zinc.

Embryo. Exterior walls of the epidermal cells thicker than the lateral; these cells are nearly isodiametric; the underlying, somewhat larger; palisade cells nearly wanting on the ends of the seed but well developed in the middle lateral portion. Fat and protein present; starch wanting. — (St. Louis, Eggert, Mo. Bot. Gard.)

PETALOSTEMON VIOLACEUS, Michx. (*K. purpurea*, Vent., Macm.)
Pl. XII. f. 3.

Testa and endosperm as in the last species. Malpighian cells somewhat shorter than in ***P. candidus.*** Light line close under the cuticle; the central canal in cross section shows numerous branches. Osteosclerids smaller towards the narrow part of the seed, and thick-walled. Nutrient layer compressed, carrying a great deal of pigment. — (Indian Territory, Bush, Mo. Bot. Gard.)

TEPHROSIA, Pers. (*Cracca*, L.)

The species studied have endosperm, chromatophores in Malpighian cells, and an abundance of fat and protein grains in the cotyledons; starch is wanting. Lysigenetic canals present in embryo, and usually an abundance of crystals of oxalate of lime in the cotyledons.

TEPHROSIA VIRGINIANA, Pers. (*Cracca virginiana*, L.)
Pl. XII. f. 4–4c. Pl. XIX. f. 1–1f.

Testa and endosperm 117 μ in thickness. Malpighian cells make up nearly half of the thickness of the testa and endosperm.

Malpighian. Cells 56 μ in length. Cuticle an even continuous layer, followed by the cuticularized zone; the narrow light line lies below the latter. Several pore-canals extend into the walls for nearly one-third of the length of the cell. Cell-cavity large at the base, containing protein grains and a chromatophore, the latter variable as to position.

Osteosclerid. Cells are thick-walled; upper and lower bars nearly equal. Intercellular spaces nearly square. Walls color blue with chlor-iodide of zinc.

Nutrient. Layer much compressed, variable as to thickness. The cells are rather thick-walled; only a small amount of pigment, tannin and some protein grains present; vascular elements occur in the lower part. Cell-walls color blue with chlor-iodide of zinc.

Endosperm. Aleurone layer nearly isodiametric, thick-walled, containing protein. This layer is followed by two or three rows of thick-walled cells with pore-canals. Walls color blue with chlor-iodide of zinc. The internal layer of the reserve cellulose consists of thick-walled, elongated cells with narrow lumen. Cells contain fat and protein.

Embryo. Cells of the first row with exterior walls thickened, smaller than those below; the interior cells are irregular with intercellular spaces; walls color blue with chlor-iodide of zinc. All of the cells of the embryo contain fat and protein, but little or no starch, and an abundance of compound crystals of oxalate of lime. Two rows of well-developed palisade parenchyma cells occur on the upper surface of seed during germination, or on the side next to the endosperm; the first row more compactly arranged than the rows below; the third is much interrupted because of the lysigenetic reservoirs. With a hand-lens one is able to readily distinguish spherical glistening bodies, somewhat irregularly distributed; higher magnification shows that these glistening bodies are surrounded by the parenchyma of the cotyledons. In some places these cells are shorter than the remaining parenchyma. In a longitudinal section these bodies are about of the same diameter. The development has not been studied, but in some sections it is possible to make out cells with a central globular body. I do not hesitate in calling the secretion reservoir lysigenetic. Tests were made with alcannin for resin, but with negative results. The same reagent indicated an abundance of fat in the other cells of the cotyledons. Check tests were made for other resins, so that there seems to be good evidence that the secretion is not resinous, nor does it contain fatty acids since potash does not destroy the contents of the reservoir, but with long-continued action they turn yellowish; with this reagent the reservoir colors a somewhat deeper brown. The reservoir failed to give tannin reaction with ferric-chloride. Sulphuric acid and iodine color the contents brown, the wall blue. Chlor-iodide of zinc acts in the same way. Delafield's haematoxylin colors the walls violet, but no action takes place on the contents of the reservoir. Fuchsine colors the contents of the reservoir bright red, much deeper than the contents of the parenchyma.

Whether the secretion receptacle may not contain poisonous products, such as have been found in young branches and flowers of *Tephrosia toxicaria*, and other species (Radlkofer and Rosenthal), I have been unable to determine. An examination of herbarium material did not reveal similar structures in parts of the plants examined (petiole). The reservoirs of the peduncle resemble those figured for *Copaifera Langsdorfii* by Tschirch in his Angewandte Pflanzenanatomie. The peduncle of *Tephrosia virginiana* has similar secretion reservoirs. *Apios tuberosa*, according to Gray's Manual, contains latex. There is no evidence that the substance in *Tephrosia* is latex. The walls of the surrounding cells color blue with chlor-iodide of zinc. — (St. Louis, Eggert, Mo. Bot. Gard.)

TEPHROSIA HISPIDULA Pers. (*Cracca hispidula*, Michx., K.)
Pl. XII. f. 2a.

Testa and endosperm are somewhat more strongly developed than in the last species, 154 μ in thickness. Malpighian cells 50 μ long; light line a sharp zone below the cuticularized layer; the cavity irregular in the lower part of the cell. Osteosclerids are longer than in *T. virginiana;* the intercellular spaces are very long. An abundance of pigment is found in the lower part of the nutrient layer. The aleurone cells are elongated, and the cell-walls of the endosperm do not color blue rapidly with chlor-iodide of zinc. Oxalate of lime crystals are abundant in the embryo, but the reservoirs for secretion are not so numerous as in the last species. These lysigenetic reservoirs also occur in the cotyledons of the Natal *Tephrosia elongata* (Coll. by Wood, Mo. Bot. Gard.), the Hawaiian Islands *T. piscatoria* (Coll. by A. A. Heller), *Tephrosia pallens* (Bernhardi collection, Mo. Bot. Garden), *Tephrosia spicata* (Florida, Curtiss, No. 4823, Mo. Bot. Gard.), *Tephrosia Schiedeana*, Schl. (Fl. Mexico, San Blas, W. G. Wright, No. 1337), and *Tephrosia leucantha*, HBK. (Pringle, Pl. Mexicanae). In *T. leucantha* and *T. Schiedeana* these reservoirs also occur in the nutrient layer. Crystals were found in all the species except the last two.

INDIGOFERA, L.

This genus has been studied by Nadelmann, who did some work on *I. tinctoria*, L. and *I. hirsuta*, L. The walls of the endosperm, in their early stages, are thin, and the cells are rich in plastic material. The young cells have what Nadelmann calls "Schleim-bläschen" imbedded in the protoplasm. The smaller mucilaginous masses unite to form a larger one. From these masses the wall is built up. The primary membrane in young seeds colors deep blue with sulphuric acid and iodine. The secondary membrane colors light blue. The tertiary membrane forms much later. It is noteworthy that the mucilaginous endosperm at no time showed transition starch. The endosperm exceeds the testa by five times its width in *I. tinctoria* and *I. hirsuta*. The white color of the seed, in cross-section, is due to the mucilaginous endosperm. The young flowers of *I. tinctoria* at the time of flowering contain indigo blue, known as indigotin.

INDIGOFERA LEPTOSEPALA, Nutt.

Pl. XIII. f. 1-1c.

Testa and endosperm vary in thickness from 83–866 μ. The cotyledons are 680 μ across, and uniform throughout.

Malpighian. Cells larger than the remainder of the testa, 30.8 μ long. Cuticle evenly developed; the wide light line below the cuticle colors light blue with chlor-iodide of zinc; the cuticularized layer takes the same color; the remainder of the cell-wall below, a darker blue. The cell-cavity is wide at the base but is abruptly contracted near the light line, and contains pigment, tannin, and protein grains.

Osteosclerid. Cells are small, wide in proportion to their length, thick-walled, and color blue with chlor-iodide of zinc.

Nutrient. This layer is much compressed. The cells are thin-walled, elongated, and contain an abundance of brown pigment and tannin.

Endosperm. The thick-walled, nearly isodiametric aleurone cells form a continuous layer; the walls are stratified; large pore-canals connect with adjoining cells; this layer is followed by the reserve cellulose. The walls are differentiated into three parts — primary, secondary, and tertiary. The stratified tertiary membrane colors blue with chlor-iodide of zinc, but not so deeply as the secondary stratified walls. The internal part of the endosperm consists of thick-walled, elongated cells with a small cavity. The cells of this part as well as of the middle portion contain protein.

Embryo. Cells of the first row, the epidermis, are smaller than those below, nearly isodiametric, with thick exterior walls. The interior cells are more loosely arranged. All of the cells contain fat and protein. The superior face of the cotyledon consists of several rows of palisade cells. Crystals of oxalate of lime are common in the interior cells.

ROBINIA, L.

Testa variously colored. Endosperm present. Nutrient layer compressed, containing pigment and tannin. The flowers and presumably the ovules contain a glucoside, robinin. The term has also been applied to the yellow coloring matter found in other parts of the tree.

ROBINIA PSEUDACACIA, L.

Pl. XIV. f. 1–1f.

This species has been studied by Nadelmann, Huss, and Holfert; its germination by Lubbock and others. Testa and endosperm uniformly developed, 249 μ thick. Cotyledons 796 μ in thickness.

Malpighian. Cells 95–98 μ long. Cuticle an even layer; cuticularized portion white; a narrow light line underneath the cuticularized layer; the cuticularized layer colors blue with chlor-iodide of zinc more rapidly than the light line, which takes on a much paler color than the rest of the cell-wall. Cell-cavity wide at the base, tapering upward. Chromatophores not observed. The cells contain pigment and some tannin.

Osteosclerid. Cells are thick-walled, elongated, less than half the length of the Malpighian cells. Chlor-iodide of zinc colors the walls blue and contents brown.

Nutrient. This layer is compressed and composed of three or occasionally more rows of elongated cells. An abundance of a yellowish-brown pigment is present in the cells; presumably this contains some robinin. The walls color blue with chlor-iodide of zinc.

Endosperm. The aleurone cells are thick-walled and contain fat and protein. Reserve cellulose consists of three or more layers of thick-walled cells with pore-canals. The cells contain protein. The internal part of the endosperm consists of thick-walled, elongated cells; cell-lumen reduced, containing but little fat and protein.

Embryo. Cells of the first row are smaller, with thick exterior walls; the cells below are larger and more loosely arranged; all of the cells contain fat and protein grains but no starch. Cell-walls color blue with chlor-iodide of zinc.

WISTARIA, Nutt.

Testa spotted with pigment, well developed. Nutrient layer well developed and differentiated into several distinct layers. Endosperm sparingly present.

WISTARIA SPECIOSA, Nutt. (*W. frutescens*, Poir. Gray's Manual, 6th ed. 134. *Kraunhia frutescens*, L., Greene.) *Pl. XIV. f. 2–2c.*

Testa strongly developed, 540–600 μ in thickness. Endosperm limited to one or two rows of cells. Nutrient layer with a great deal of pigment.

Malpighian. Cells quite uniform, 166 μ long. Cuticle irregular, followed by a narrow cuticularized layer, which refracts light strongly; the wide light line follows the cuticularized portion; the pore-canals extend beyond the line. When the cells are cut at right angles or obliquely the pores appear disconnected, with small projections; the projections between the pores color blue with chlor-iodide of zinc. The cell cavity is wide at the base, tapering upward. Each cell usually contains a round chromatophore; occasionally it is elliptical or nearly square. With chlor-iodide of zinc the walls, light line, and cuticularized layer color blue. Some of the cells contain a brown or violet pigment. Tannin and some protein also occur.

Osteosclerid. Cells small when compared with the Malpighian, 20.4 μ long. The upper and lower bar nearly equal. Cell-cavity rather large and containing protein, some pigment, and tannin.

Nutrient. This layer is differentiated into two parts: (1) a narrow layer consisting of two to four rows of elongated cells containing some pigment, (2) three or four rows of much larger, thin-walled cells.

Mycotic. In this layer the cells are elongated, thick-walled, and somewhat irregular, comprising ten to fourteen rows; also some pigment.

Nucellus. Consists of one or two rows of thick-walled cells.

Endosperm. This consists of a narrow continuous layer of one or two rows of cells — the aleurone, whose walls are thickened. The cells contain protein grains.

Embryo. Cells of the first row smaller than those below, forming a continuous row; the exterior walls thickened; cells below are more loosely arranged, thinner-walled, a pore-canal present, and a triangular intercellular space at their angles. Palisade parenchyma wanting. The cells, except the first row, contain an abundance of large starch grains. Protein grains and fat in all of the cells.

ASTRAGALUS, Tourn.

A considerable number of species have been studied by Schleiden and Vogel, Huss, Nadelmann, Harz, Holfert, Strandmark, Mattirolo and Buscalioni, Chalon and others. The presence of endosperm has been noted by several observers, and in our American species, so far as I have studied them, it is present. It is present in the European *A. glycyphyllus*, *A. lamosus*, and *A. Onybrychis*. The testa is well developed. The osteosclerids are longitudinally striated in some species.

ASTRAGALUS MEXICANUS, A. DC.

Pl. XIII. f. 3–3b.

Testa and endosperm 130–145 μ thick. Cotyledons 664–830 μ across.

Malpighian. Cells 70 μ long. Cuticle forms an even layer; the narrow light line occurs under the light-colored cuticularized layer; several pores project into the walls below the light line; cell-cavity broad at the base, narrowing upward, constricted in several places. Cells carry a great deal of pigment, several chromatophores, and some protein grains.

Osteosclerid. Cells 14 μ long. Walls thickened and striated. Intercellular spaces large and elongated.

Nutrient. Cells of this layer much compressed, in three to six rows, thin-walled, containing a great deal of pigment and protein.

Endosperm. Variable as to quantity. The aleurone cells are thick-walled, forming a continuous row; the reserve cellulose is variable; the cells are thick-walled and on the addition of water are gelatinized; the internal layer of the endosperm consists of thick-walled, elongated cells. All of the cells contain protein.

Embryo. The cells of the first row are nearly isodiametric, continuous; exterior walls thickened. The cells below have thinner walls and are more loosely arranged. Fat and protein grains fill the cells, but starch is absent.

ASTRAGALUS CANADENSIS, L. (*A. carolinianus*, L.)

Pl. XIII. f. 5–5b.

Testa and endosperm 90–110 μ thick. The species agrees with *A. mexicanus* in having most of the yellow pigment in the Malpighian cells. The cells are 22 μ long, each containing one or more chromatophores. A small intercellular space occurs below the Malpighian cells. Longitudinal striae of the osteosclerids are not marked. Nutrient layer agrees with that of the last species. Endosperm is well-developed laterally. All of the cells of the endosperm contain protein. Embryo as in *A. mexicanus*. For complete reactions see Table A.

OXYTROPIS, DC. (*Spiesia*, Neck.)

Anatomically this genus is closely related to *Astragalus*. Endosperm is present in the species studied. One species was studied by Chalon.

OYTROPIS LAMBERTI, Pursh. (*S. Lamberti*, Pursh, Lamb.) *Pl. XIII. f. 4.*

Testa and endosperm 170–175 μ. This, the so-called loco weed, is said to cause disturbances in animals, but alkaloids have not been found in the seed or any other part of the plant.

Malpighian. Cells 40–42 μ long. Cuticle somewhat uneven; the narrow well-marked cuticularized layer colors blue with chlor-iodide of zinc; the light line occurs below the cuticularized layer, and this also colors blue; the remainder of the cell-wall takes on a darker blue color. Cells contain an abundance of pigment, tannin, and some plastic material.

Osteosclerid. Cell-walls thickened, not prominently I-shaped, but with an elongated intercellular space.

Nutrient. Layer consists of thin-walled elongated cells, from ten to twelve rows. Pigment more abundant in lower than in upper part. Walls color blue with chlor-iodide of zinc.

Endosperm. The aleurone layer consists of thick-walled cells; the underlying thick-walled cells of the reserve cellulose become mucilaginous on the addition of water. The internal part consists of thick-walled, elongated cells. The cells contain protein.

Embryo. Cells of the first row smaller, with thick exterior walls; cells below not so compact and with thinner walls.

Cell-walls color blue with chlor-iodide of zinc. Starch is absent but cells contain fat and protein.

OXYTROPIS DEFLEXA, DC.

Pl. XIII. f. 2.

Malpighian cells do not differ essentially from those of *O. Lamberti.* The walls of the osteosclerids are thick; the nutrient layer is much compressed and thin-walled. Aleurone layer prominent, followed by the thick-walled mucilaginous endosperm, and the narrow, elongated, thick-walled internal layer. Embryo as in last species.

GLYCYRRHIZA, Tourn.

Schleiden and Vogel, and Chalon, studied the genus with reference to the presence of endosperm; the mucilaginous character of this by Nadelmann. Brandis has also studied the genus. *G. echinata* is without starch but contains an abundance of fat and protein. Endosperm is more abundant in *G. lepidota* than in *G. echinata.*

GLYCYRRHIZA LEPIDOTA, Pursh.

Pl. XV. f. 6.

Testa and endosperm 490–500 μ thick. Endosperm variable in different parts of the seed, but usually well developed.

Malpighian. Cells 70–75μ long. Cuticle somewhat irregular; the light-colored cuticularized layer is followed by a narrow but sharply marked zone, the light line; cell-cavity is large at the base, gradually tapering upward. Pore-canals extend into wall beyond the light line. Cells contain pigment and some plastic material.

Osteosclerid. The I-shaped cells are thick-walled, with small projections somewhat similar to those shown for *Ervum Lens* by Mattirolo and Buscalioni. The intercellular space is elongated. The cells attain their greatest development in the hilar region. All of the cells carry some pigment and plastic material.

Nutrient. This layer is much compressed and thin-walled; cells number from four to six rows. Pigment is most abundant in the lower part of the layer.

Endosperm. Aleurone layer consists of nearly isodiametric thick-walled cells. The mucilaginous reserve cellulose is variable in quantity. Cell-walls differentiated into primary, secondary, and tertiary. Pore-canals large. Internal part of the endosperm consists of thick-walled, elongated cells. All of the cells contain protein grains.

Embryo. Cells of the outer row smaller than those within; exterior walls thickened, those below more loosely arranged than the epidermal; more compact and with thicker walls than those of *Astragalus mexicanus.* Cells contain fat and protein grains but no starch.

PAPILIONACEAE — Hedysareae.

AESCHYNOMENE, L.

Endosperm has been found in several species of *Aeschynomene. A. Selleri, A. falcata,* and *A. fluminensis* were studied by Schleiden and Vogel. *A. paludosa* was studied by Payen with reference to the nature of cellulose. Lubbock, who studied the germination of *Hedysarum coronarium,* which belongs to the same group, states that endosperm is absent from this species. He also studied *Aeschynomene aspera* but says nothing about the endosperm. Marloth studied *Hedysarum* with reference to its protection. The *Hedysareae* appear to vary in regard to the presence of starch. *Ornithopus sativus* is without starch, while *Onobrychis sativa* has an abundance of round starch grains. Harz gives a key for some of the European genera, based on the abundance of starch. *Hedysarum flexuosum, H. fruticosum* and *Coronilla varia* have an abundance of starch. In *H. capitatum, Coronilla glauca,* and *C. coronata,* starch grains are not abundant. Iodine does not always color the starch. In the second group, the starch is colored only on the addition of potassium hydrate. *C. scorpioides* is without starch.

AESCHYNOMENE HISPIDA, Willd. (*A. virginica,* L., BSP.)
Pl. XV. f. 4.

Testa and endosperm 318.8 μ thick. Endosperm somewhat variable.

Malpighian. Cells 80–82 μ long. Cuticle uniformly developed, the narrow cuticularized layer followed by the well-developed light line; cell-cavity gradually tapering from the base; pores extend much beyond the light line. Cells contain plastic material.

Osteosclerid. Cells I-shaped, with uniform, elongated, intercellular spaces. The walls are thickened and the cells contain some plastic material.

Nutrient. This layer is much compressed, consisting of three to six rows of cells containing pigment.

Endosperm. Variable in thickness. Aleurone layer well developed with thick-walled cells. Cells of the reserve cellulose are thick-walled with large pore-canals. The walls are differentiated into three parts as in *Glycyrrhiza* and many other genera. The internal part of the endosperm consists of thick-walled, elongated cells with a small cell-cavity. All of the cells contain fat and protein grains.

CORONILLA, Tourn.

The genus *Coronilla* has been studied by Chalon, who found endosperm uniformly present in a large number of species examined by him. *C. montana* was studied by Nadelmann, who found a small amount of mucilaginous endosperm present, as well as starch in the cotyledons. Harz noted the occurrence of starch in the cotyledons of this species. The same species is described in detail by Mattirolo and Buscalioni. Lubbock studied the germination of *C. juncea* but does not describe the seed. Parts of the plant are said to be poisonous, although it is used for forage.

CORONILLA MONTANA, Scop.

Pl. XXII. f. 2. Pl. XXIII. f. 3.

I was unable to obtain good seed of *C. varia* and therefore substituted *C. montana.* Testa and endosperm 125–230 μ thick. Testa below the Malpighian cells usually 50 μ thick.

Malpighian. Cells 40–49 μ long, thick-walled and deep brown; light line removed some distance from the cuticle. When sections are treated with ferric chloride the walls and contents give the reaction for tannin.

Osteosclerid. Cells are rather short, thick-walled, and with somewhat elongated intercellular spaces. With sulphuric acid and iodine the walls give the reaction for cellulose.

Nutrient. This layer is much compressed, differentiated into two parts; cells of the lower part are thicker-walled, with lumen much reduced. The cells contain tannin and pigment.

Endosperm. Variable in amount. The aleurone layer consists of thick-walled cells containing protein; the cells below are mucilaginous, and thick-walled; the internal part of the endosperm consists of thick-walled elongated cells. The reserve cellulose cells contain some protein.

Embryo. The first row of cells smaller than those below, the interior cells more loosely arranged; palisade cells of the inner face of the cotyledons comprise two rows. All of the cells contain fat and protein but no starch. — (Curling-Joad Herb., Mo. Bot. Gard.)

HEDYSARUM, Tourn.

Endosperm is but slightly developed, as Nadelmann indicates for *H. sibiricum.* The same species was studied by Strandmark. Schleiden and Vogel have given an account of *H. obscurum.* Chalon studied seven species with reference to the presence or absence of endosperm. In the species studied by myself it is not well developed.

HEDYSARUM BOREALE, Nutt.

Pl. XV. f. 7.

Testa and endosperm 95–100 μ in thickness. Endosperm and nutrient layers vary somewhat.

Malpighian. Cells 52–55 μ long. Cuticle somewhat uneven, and below it the narrow, sharply defined, cuticularized layer with its conical projections; the well marked but narrow light line is below the cuticularized layer; the cell-cavity is wide at the base, gradually tapering upward; each cell contains one large and occasionally several smaller chromatophores.

Osteosclerid. Cells thick-walled, I-shaped, with an elongated intercellular space. Chlor-iodide of zinc colors the walls less intensely than the Malpighian cells.

Nutrient. The layer is compressed; the cells are thin-walled, elongated, and contain pigment and protein. Walls color pale blue with chlor-iodide of zinc.

Endosperm. Aleurone cells thick-walled with the pore-canals slightly irregular. The cells are larger than in *Aeschynomene* or *Astragalus.* In most parts of the seed the aleurone is the extent of the endosperm; laterally, however, more endosperm occurs, and here it is mucilaginous. Walls color blue with chlor-iodide of zinc. Cells contain fat and protein.

Embryo. The cells of the first row smaller and nearly isodiametric, the exterior walls thickened; cells below larger, longer than wide. The walls color blue with chlor-iodide of zinc. The cells contain an abundance of fat and protein. On the addition of iodine a few elliptical or spherical starch grains may be seen. On the addition of chlor-iodide of zinc a great many more grains are colored. — (Wyoming, Nelson, Mo. Bot. Gard.)

DESMODIUM, Desv. (*Meibomia*, Adans.)

Malpighian cells carry pigment in variable amounts. Osteosclerids are of the characteristic I-shape. Chalon studied several species with reference to endosperm, finding it present in *D. floribundum*, G. Don., *D. canadense*, DC., *D. gyrans*, DC., *D. incanum*, DC., *D. latifolium*, DC., *D. gangeticum*, DC., *D. uncinatum*, DC., *D. triquetrum*, DC., and *D. umbellatum*, DC. All of the species which I have examined contain endosperm, *e. g.*, *D. nudiflorum*, DC., *D. canescens*, DC., *D. strictum*, DC., and *D. Dillenii*, Darl. Lubbock studied the germination of *D. canadense,* but does not describe the seed.

DESMODIUM CANESCENS, DC. (*M. canescens*, L., Kuntze.) *Pl. XV. f. 3a.*

Testa and endosperm 140–150 μ thick. The testa is uniform but the endosperm is variable.

Malpighian. Cells 50–52 μ in length. Cuticle uneven; cuticularized layer narrow; light line runs close under the cuticularized layer; several pore-canals extend into the wall below the light line, which connect in part with the cell-cavity. The cell-cavity is large at the base but narrows rather abruptly, and in upper part occurs as a narrow cavity to the light line, where it widens again. Sections which had passed through potassium hydrate before mounting in glycerine, after the lapse of several years colored uniformly dark brown.

Osteosclerid. Cells I-shaped, with elongated intercellular spaces, and thickened walls. Cells contain tannin and pigment. Sections treated with potassium hydrate change from a yellowish to a dark brown color.

Nutrient. Layer compressed, consisting of from four to six rows of cells which are elongated and thick-walled. Contain but a small amount of pigment and some protein grains.

Endosperm. Cells of the aleurone layer continuous, nearly isodiametric, thick-walled, containing protein grains and fat; the walls of the reserve cellulose differentiated into three parts, primary, secondary, and tertiary; internal layer of endosperm is made up of thick-walled, elongated cells. The cells of the reserve cellulose layer contain protein and fat.

Embryo. Cells of the first row nearly isodiametric; the exterior walls of the epidermis are thickened; cells below more loosely arranged with intercellular spaces. Inner face of the cotyledons with isodiametric epidermal cells, and several rows of palisade cells, the outer row much larger. Procambial bundles more than ten. All of the walls of the cotyledons color blue with chlor-iodide of zinc. Cells contain protein and fat but no starch. — (Sapulpa, Indian Terr., Bush, Mo. Bot. Gard. — East St. Louis, Ills., Pammel.)

DESMODIUM STRICTUM, DC. (*M. stricta*, Pursh, Kuntze.)
Pl. XV. f. 2.

Testa and endosperm 90–100 μ thick. Malpighain cells 50 μ long; light line below the cuticularized layer, but further removed than in the last species; the yellow pigment is abundant in freshly mounted specimens. Nutrient layer compressed; the cells are elongated and contain an abundance of pigment. Aleurone layer as in *D. canescens.* Walls of the reserve cellulose cells greatly thickened, in some cases very irregular; the cell-cavity small. Internal layer of endosperm consists of elongated, thick-walled cells. Embryo as in last species.

DESMODIUM NUDIFLORUM, DC. (*M. nudiflora*, L., Kuntze.)
Pl. XXIII. f. 2.

Testa and endosperm 90–100 μ thick. Malpighian cells 42 μ long; cuticle even; light line under the cuticularized layer. Pigment mostly in the lower part of the cell-cavity. Osteosclerids 12 μ long, I-shaped, thick-walled, with elongated intercellular spaces. Nutrient layer compressed, composed of somewhat elongated cells. Endosperm not strongly developed; the aleurone layer continuous, followed by several rows of thick-walled cells.

LESPEDEZA, Michx.

The testa in this genus is usually yellowish. In structure it is much like that of *Desmodium* but in some of the species endosperm is more abundant than in *Desmodium*. Schleiden and Vogel recorded endosperm for the genus, and stated that it is differentiated into three parts. Chalon also indicated its presence in several species of the genus. Lubbock studied the germination of *L. angustifolia*, Ell., but the seed is not described. Protein and fat occur in all of the cells of the embryo. Starch is absent.

LESPEDEZA VIOLACEA, Pers.

Malpighian. Cells 50 μ long; cuticle an even layer which colors brown with iodine; the cuticularized layer is light colored and prominent, it colors blue rapidly with chlor-iodide of zinc. The light line occurs below the cuticle, with numerous pores extending into the wall below. Cell-cavity somewhat irregular, large at the base, with a single chromatophore; in addition, the cells contain a yellowish pigment and tannin.

Osteosclerid. Cells 16–28 μ long, thick-walled and slightly constricted in the middle; cell-cavity larger in the lower part of the cell; the intercellular space is elongated. Walls color blue with chlor-iodide of zinc.

Nutrient. This layer is compressed. Cells thin-walled and elongated. Some of the larger measure 11.2×56 μ. Cells of the inner part longer than broad, thin-walled, containing a great deal of yellowish-green pigment. The walls color blue with chlor-iodide of zinc.

Endosperm. The aleurone layer continuous, consisting of small, thick-walled, nearly isodiametric cells; the contents color red very rapidly with fuchsine, making a strong contrast with the nutrient layer and the rest of the endosperm. The cells of the mucilaginous reserve cellulose are thick-walled, with a small cavity. The middle lamella stains blue with chlor-iodide of zinc when it is allowed to act for some time. The mucilaginous walls color faintly at first. The internal part of the endosperm consists of thick-walled elongated cells.

Embryo. Epidermal cells nearly isodiametric; exterior walls thickened; the cells below are elongated and more loosely arranged, with small intercellular spaces; two rows of palisade cells occur on upper face, a third is interrupted and connects with the procambial vessels. The cells contain protein and fat but no starch. Walls color blue with chlor-iodide of zinc. — (Sapulpa, Indian Terr., Bush, No. 1846, Mo. Bot. Gard. — St. Louis, Mo., Pammel.)

LESPEDEZA RETICULATA, Pers. (*L. frutescens*, L., Britton.)

Testa and endosperm 108–116 μ thick. Malpighian cells well developed; endosperm somewhat variable, reaching its greatest development on the sides.

Malpighian. Cells 56 μ long. Cuticle somewhat uneven; cuticularized layer narrow, followed by a narrow but well marked light line; a second less sharply defined zone occurs in the lower part of the Malpighian cells. Several pores extend into the wall below the upper light line. Cells contain a large chromatophore somewhat variable as to position. Yellowish pigment and tannin abundant, also smaller granules of plastic material.

Osteosclerid. Cells thick-walled, 14 μ long, containing protein grains, some pigment and tannin. The intercellular spaces are elongated.

Nutrient. This layer is much compressed, the cells are thin-walled, elongated, and contain a great deal of pigment and tannin.

Endosperm. Aleurone cells longer than broad. The reserve cellulose below is not well developed; all of the cells contain fat and protein.

Embryo. Cells of the first row smaller than those below, having thick exterior walls; the lateral walls are thinner. Cells below not so compactly arranged as the epidermal. All of the cells contain fat and protein but no starch.

LESPEDEZA STUVEI, Nutt.

Pl. XV. f. 3b. Pl. XVI. f. 5.

Testa and endosperm 116–132 μ thick. Light line occurs close under the cuticle. Malpighian and osteosclerid cells contain an abundance of pigment and tannin; the latter are greatly elongated in the hilar region. Endosperm more strongly developed than in *L. reticulata.* The reserve cellulose gelatinizes readily on the addition of water. The internal layer consists of thick-walled elongated cells with a narrow lumen. Cells of embryo as in other species. Contains fat and protein but no starch.

LESPEDEZA CAPITATA, Michx.

Pl. XVI. f. 4.

Testa and endosperm 90–100 μ thick. Light line occurs close under the cuticle. A large spherical chromatophore occurs in the pigmented Malpighian cells, which is variable as to its position in the cell. The long pores extend to the middle of the cell. The osteosclerids are short. The nutrient layer is compressed, containing much pigment. Endosperm as in *L. Stuvei;* the aleurone cells are thick-walled, and the reserve cellulose is mucilaginous. Embryo as in the other species, containing fat and protein but no starch.

STYLOSANTHES, Sw.

Schleiden and Vogel were unable to determine whether endosperm occurred in the genus. It is present though much reduced.

STYLOSANTHES ELATIOR, Swartz. (*S. biflora*, L., BSP.)

Pl. XXII. f. 1–1c.

Thin testa and endosperm 50–65 μ thick.

Malpighian. Cells 14 μ long, and 8–9 μ in width. Cuticle thin and even; a narrow cuticularized layer under the cuticle, and below it the narrow light line; cells with a rather large cell-cavity and containing considerable tannin. Pore-canals numerous and very plainly marked when treated with chloral hydrate. In surface view they appear as short canals much as in *Arachis*. Specimens treated with potassium hydrate and then mounted in glycerine are colored reddish. The whole Malpighian layer on the addition of iodine colors brown except the light line which remains as a translucent zone. Ferric chloride, when allowed to act for some time, colors the walls and contents bluish-black, in strong contrast with the cells below.

Osteosclerid. Cells 10–14 μ long, thick-walled. Intercellular spaces elongated; frequently the cells are very widely separated. Cells contain protein grains. Walls are not greatly thickened, not nearly as much as in *Lespedeza.*

Nutrient. This layer is much compressed, reaching its greatest development in the hilar region. The cells are elongated and thin-walled. Contain pigment and a little tannin. Lignified only where the vascular elements occur.

Endosperm. This consists mainly of one layer of cells, the aleurone, but an internal layer, made up of elongated thick-walled cells, may be made out in some parts of the seed.

Embryo. The epidermal cells are smaller than those below; exterior walls thickened. Palisade cells on the interior face of the cotyledon arranged rather compactly. All of the cells contain protein and a great deal of fat, also simple and compound crystals of calcium oxalate, one or occasionally several in nearly every cell. — (Sapulpa, Indian Terr., B. F. Bush, No. 111.)

ARACHIS, L.

Several accounts have been given of the testa of the peanut. The earliest account of the genus is by Chalon, who gave the essential facts with reference to its structure. Schleiden and Vogel gave an account of the cotyledons. Later Harz, and Mattirolo and Buscalioni, gave an account of the structure of the seeds. Pfaefflin, who studied more especially the tracheid island, also describes other parts of the testa. Godfrin discusses the comparative anatomy of the cotyledons. In many respects the genus closely resembles *Stylosanthes.* The protective features are replaced by the pod in both genera. Marloth has discussed these features for the peanut. The Malpighian cells are short, and the light line is indistinct or wanting. The osteosclerid layer is suppressed. The related *Zornia bracteata*, J. F. Gmel. has well-developed Malpighian cells and an osteosclerid layer. The testa in both genera is prominently veined. The seeds are very oily, but those of *Arachis* more so than those of *Stylosanthes*. Endosperm much reduced. Many chemical analyses have been made. These may be found in König, Harz, and Jenkins and Winton.

ARACHIS HYPOGAEA, L.

Pl. XXII. f. 3-3g.

Testa 112 μ thick. The endosperm occurs as a single row, the aleurone. The outer part of the testa brown, the inner yellow. It is differentiated into three parts; the nutrient layer is, however, divided.

Malpighian. Cells short, nearly as broad as long, measuring 16×20 μ. Cuticle delicate. Numerous thickened processes from the cuticularized layer, with small pore-canals; surface view similar to that of *Stylosanthes;* light line is indistinct in the upper part of the cell. Cavity wide at the base, narrow in the upper end. Cells contain but a small amount of pigment; the walls are colorless, but color blue rapidly with chlor-iodide of zinc. Cells contain a small amount of tannin.

Osteosclerid. This layer is suppressed.

Nutrient. Cells thin-walled and elongated, containing a reddish and a yellow pigment. The cells above are larger. The lignified vascular elements occur in the nutrient layer above the mycotic. A second part of the nutrient layer below the mycotic is thick-walled and compressed, containing a yellow pigment and an abundance of tannin.

Mycotic. This layer is compressed. The cells are thin-walled and elongated, star-shaped, colorless, and without pigment.

Endosperm. This layer is reduced to a single row of thick-walled cells, the aleurone, containing protein.

Embryo. Cells of the outer row with the exterior walls thickened, much smaller than those below; the cells of the internal part of the cotyledon like those of the outer part and followed by cells which are elongated at right angles, gradually becoming larger, with small intercellular spaces. The walls of all the cells below the epidermal layer are provided with pores. The epidermal cells of the caulicle are much larger, but smaller than those below. All of the walls color blue with chlor-iodide of zinc. Starch colors blue with iodine. The cells have comparatively few round or elliptical starch grains, with an elongated rift, which are soluble in weak hydrochloric acid. Alcannin colors the oil plasma red in the course of a few seconds. The aleurone, which is imbedded in the oil plasma, is very abundant. When mounted in glycerine beautiful aleurone grains with crystalloid and globoid come out. As a rule there is but a single crystalloid in the grain, each showing one globoid; the latter does not, however, always show.

CHAPMANNIA, Torr. & Gray.

The testa is prominently veined, delicate, whitish and, with endosperm, 33 μ thick, except in hilar region, where it measures 140 μ. The endosperm is but sparingly developed, consisting of a single row of cells, the aleurone layer.

Chapmannia is undoubtedly closely related to *Arachis* and *Stylosanthes*. It is the only genus studied, from which the Malpighian cells are absent. The epidermal cells are thin-walled; the light line is absent. The osteosclerid layer is present and consists of elongated cells with intercellular spaces, or it is but little differentiated.

CHAPMANNIA FLORIDANA, Torr. & Gray.
Pl. XVII. f. 5.

The epidermal cells are usually isodiametric, the exterior walls but slightly thickened; the lateral walls are thin. No pore-canals from the surface as in *Arachis;* the large cell-cavity contains a nucleus.

Osteosclerid. The cells are thin-walled, larger than the epidermal cells, and occur only in the hilar region; intercellular spaces vary in size.

Nutrient. In most parts of the seed this layer follows the epidermis ; it is much compressed, the cells are thin-walled and elongated. Vascular elements abundant in this layer. The thick-walled pigment layer and the mycotic are absent.

Endosperm. A single row of thick-walled cells, the aleurone, occurs especially in the hilar region. Cells contain protein.

Embryo. The epidermal cells below the endosperm are mostly isodiametric followed by more loosely arranged cells with thinner walls; the internal part of the cotyledons, with an epidermis similar to that of the outer part, having several rows of palisade cells. Cells contain an abundance of fat and protein.— (Fla., A. S. Hitchcock, Mo. Bot. Gard.)

ZORNIA, J. F. Gmel.

The testa of this genus is very different from that of *Arachis*, *Stylosanthes*, and *Chapmannia.* Even before making a section, the hardness of the testa is evident. The genus is allied to *Desmodium* and *Lespedeza* rather than to the other members of the subtribe.

ZORNIA BRACTEATA, J. F. Gmel.

Malpighian. Cells nearly half as long as the remainder of the testa, thick-walled. Cuticle evident; cells with longitudinal pore-canals; cuticularized layer inconspicuous; light line near the cuticularized layer. Cells carry some pigment.

Osteosclerid. Cells I-shaped, with large intercellular spaces ; they contain a great deal of pigment.

Nutrient. Layer compressed, consisting of four or five rows of pigmented cells.

Endosperm. Reduced to a single row of cells, the aleurone.

Embyro. Epidermal cells smaller than the parenchyma cells below, isodiametric ; the palisade cells smaller than the underlying parenchyma, narrow and in two to three rows. The procambial bundles are small. Reserve material consists of fat and protein. Starch is absent.

PAPILIONACEAE — Vicieae.

VICIA, Tourn.

Various species of the genus have been studied by Godfrin, Schleiden and Vogel, Beck, Harz, Mattirolo and Buscalioni, Nadelmann, Chalon, Macchiatti, Tschirch, Oesterle, Russow, Pringsheim, Monnier, Sempolowski, Dahmen, Holfert, Bischoff, Harberlandt, Sachs, and Huss.

Schleiden and Vogel, as well as Chalon, considered the seeds of the genus exalbuminous. Bischoff recorded endosperm for the genus as early as 1833, and Beck much later indicated its presence in some species, but Nadelmann was unable to find endosperm in the genus. In the species which I have studied endosperm was present, though often reduced to the aleurone cells accompanied by thick-walled, elongated cells — the internal layer. Beck figures and describes endosperm for *Vicia Faba*, and Macchiatti, for *V. narbonensis*. The testa of the genus is variously pigmented — brown, yellow, or sometimes almost black. Malpighian cells elongated and large. Beck records silica in the Malpighian cells of *V. Faba*. I have not been able to confirm this. Chromatophores present. Osteosclerids elongated, thick-walled, and I-shaped.

The following brief characters of species not studied by me are taken from Harz. The Malpighian cells of *Vicia narbonensis*, L. are 180–183 μ long, colored dark brown. Osteosclerids short. The nutrient layer is divided into three parts. Endosperm absent according to Harz. Palisade cells of the embryo absent. Large intercellular spaces in the cotyledons, and an abundance of starch. *Vicia lathyroides*, L. has shorter Malpighian cells which are somewhat variable in size owing to the presence of small depressions between the ridges. The depressions are 45 μ long and the projections are 75–80 μ long. Cotyledons with large starch grains. *V. hybrida*, L. has long, dark brown Malpighian cells. Endosperm absent. Starch in the cotyledons not as abundant as in the last species. The Malpighian cells of *V. lutea*, L. are 110–115 μ long. The upper part of the cell is colorless, the lower brown. Endosperm reduced or absent. Cotyledons with an abundance of starch grains. The Malpighian cells of *Vicia sepium*, L., in the dark-colored varieties, contain a great deal of pigment and tannin. Starch grains 14–26 μ in diameter. In *V. Michauxii*, Spr., Malphigian cells 56.8 μ long, upper part colorless. Osteosclerids 10–12 μ long. Cells of cotyledons somewhat elongated, containing oval, spherical, or ovate starch grains, 11–18 μ in diameter. The seeds of several species are of economic importance as food.

VICIA SATIVA, L.

Pl. XVI. f. 1–2.

This species has been studied by Harz, Tschirch and Oesterle, Beck, and Sempolowski. Testa irregular, with small projections, 126 μ thick. Endosperm reduced to a single layer. The presence of endosperm has been indicated by the above writers. Beck speaks of an aleurone spot (Aleuronefleck) in the epidermal cells of the cotyledons of this and other species of the genus *Vicia*.

Malpighian. Cells 72–75 μ long, pointed at the upper end; cuticle very irregular because of the projections; cuticularized layer most prominent in the depressions; pores project into the walls below the light line, and partly connect with the cell-cavity; the upper part of the cell is not pigmented, or very little. The light line occurs just above the pigmented part of the cell. Cell-cavity is large at the base, narrows upward, becoming much constricted below the light line, and above widens again. Small lateral projections or pores extend into the wall at right angles to the cavity. A large chromatophore, some pigment, and small granules occur in the cavity. The walls in lower part of cell are colored bluish-brown.

Osteosclerid. Cells are thick-walled, 13–16.8 μ long, longitudinally striated. Upper and lower cross-bars nearly equal; the intercellular spaces elongated. Tschirch and Oesterle state that this layer is not very strongly developed, but in specimens which I have examined it is well developed. These cells are more or less variable, as indicated by Harz, who states that they are from 11–13 μ long.

Nutrient. This layer is differentiated into two parts; the upper consists of thin-walled, elongated cells with a yellowish pigment; the cells of the lower part are larger, thin-walled and elongated, containing a brown pigment.

Nucellus. This consists of a narrow zone of compressed cells.

Endosperm. Occurs in the form of thick-walled elongated cells with a narrow cell-cavity. Usually only one or two rows of cells.

Embryo. The outer row of cells of the cotyledon is continuous. The exterior walls are thickened; cells below are more loosely arranged; small intercellular spaces in the angles of the cells; the epidermal cells contain fat and protein, the others in addition an abundance of spherical or elliptical starch grains measuring 25×22.5 μ–50×25 μ. Palisade cells wanting.

VICIA FABA, L.

Pl. XVI, f. 6. Pl. XXVI. f. 2–2j.

The earliest study of this species dates back to Bischoff, who indicated its general structure and noted the presence of endosperm. A more detailed account was given by Sempolowski, followed by Beck. Both writers note the presence of endosperm, although these writers both erred with reference to endosperm, since they considered the inner part of the testa to be endosperm. Chalon, as well as Schleiden and Vogel, stated that it is exalbuminous. I fully agree with Harz that endosperm is absent or sparingly developed. Tschirch and Oesterle refer to the layer of cells which follows the inner part of the testa in *Phaseolus multiflorus* as perisperm. This layer in *Vicia Faba* agrees with that of the scarlet runner, but it is difficult to say except from developmental studies whether this is to be regarded as perisperm or endosperm. Pringsheim and Nobbe also studied the species; and Holfert, with reference to the nutrient layer. Germination of the seeds was studied by Sachs, Marek and others. Dahmen studied the funiculus, and Le Monnier the nervation. Comparative studies were made by Harz, Tschirch and Oesterle, and Mattirolo and Buscalioni.

Economically the seed is of considerable importance. Many chemical analyses have been made; these are compiled by König, Jenkins and Winton, and Harz. The latter also records specific weight and other physical properties.

Malpighian. The cells are 185–200 μ long. Harz gives the length as 135–185 μ. This varies somewhat in different varieties. The form studied was sold under the name of broad bean — a large-seeded cultivated garden variety. Cuticle slightly irregular; light line below the cuticularized layer; cell-cavity irregular, constricted at several places, conspicuously enlarged below the middle, then usually tapering upward. Lateral canals project into the walls as in *V. sativa*. Beck mentions the occurrence of a silicified body in the cell-cavity, but I have been unable to make this out. One or more conspicuous chromatophores occur in the cell-cavity. In addition to the lateral pores, long longitudinal canals extend from the surface. These in some cases connect with the cell-cavity below the light line or at the constricted partition. The cells are colored brown, especially the lower part. With chlor-iodide of zinc the cuticularized layer and a broad clear band below, the light line, color blue rapidly.

Osteosclerid. The osteosclerids vary in length from 70–140 μ. Harz gives their length at 58–68 μ, becoming larger in the hilar region; here assume considerable importance, comprising more than one row of cells. The walls are greatly thickened and frequently have lateral processes. In part these cells are joined to the thick-walled parenchyma. In parts of the seed away from the hilum and raphe the cells are prominently marked with longitudinal canals.

Nutrient. This layer is differentiated into two or three parts; the cells are thin-walled, but in the lower part of the layer thicker-walled. Contents stain deeply with fuchsine. The lower portion contains an abundance of pigment, deposited in two forms, one in large scattered elliptical or spherical masses darker in color than the pigment of the remaining cells. The vascular elements are contained in the nutrient layer.

Endosperm. The endosperm consists in the main of somewhat elongated cells with mucilaginous walls; the contents consist of protein.

Embryo. The exterior walls of the epidermis thick; the walls of underlying cells less thickened; towards the interior the cells become larger; the internal face of the cotyledons without palisade parenchyma, but the underlying cells much larger than the epidermal. Procambial elements are well developed, with well formed spiral ducts. Cells of the cotyledons contain an abundance of starch and protein but little fat.

VICIA AMERICANA, Muhl.

Pl. XXVI. f. 1-1c.

Testa and endosperm greenish-brown, somewhat glossy, 160–175 μ thick; Malpighian cells 55 μ long, irregular with conical points; cuticle thick, upper part colored brownish; light line a distinct zone below the brown portion. When treated with fuchsine the light line stands out as a nearly colorless zone. With chlor-iodide of zinc the walls color bluish-black except the light line, which takes on a lighter blue color. The cell-cavity is wide at the base but becomes narrow below the light line. Several conspicuous pores extend into the walls from the cuticularized layer. Cells contain tannin and chromatophores. The osteosclerids are 20–30 μ long, I-shaped. Prominent longitudinal pore-canals occur in the hilar region; in this region more than one layer of cells occur. Cells contain much tannin. Nutrient layer green; pigment occurs in masses or apparently as distinct grains. The lower part of this layer is without pigment. Nutrient layer is followed by what appears to be the nucellus. A single layer of cells next to the embryo is certainly endosperm. The cotyledons have a yellow color but when mounted in water lose this color. The cells of the first row in the cotyledons are nearly isodiametric, followed by larger cells, with intercellular spaces, having pore-canals in the walls. Palisade cells absent. Cells of cotyledons contain an abundance of starch and protein and some fat. — (Pullman, Washington, Lake and Hall, Mo. Bot. Gard.)

LATHYRUS, Tourn.

Many of the species carry a brown pigment with a well-developed testa. Endosperm much reduced or wanting. Schleiden and Vogel record its occurrence for *L. tingitanus* and its absence from *L. tuberosus*. Chalon records it as absent from the genus. His conclusions were based on the study of eight species, including those studied by Schleiden and Vogel.

In *L. venosus* and *L. maritimus* the endosperm consists of but a single layer of cells. Harz indicates the presence of some endosperm in parts of the seed of *L. sativus*. Starch is abundant in all of the species. Huss studied *L. Cicer*, *L. pratensis* and *L. sylvestris* with reference to the taking up water by the cotyledons. Holfert studied the nutrient layer of *L. sylvestris*. Good accounts of *L. sativus*, L. are given by Tschirch and Oesterle, and Mattirolo and Buscalioni. Strandmark gives a short account of *L. latifolius*. Analyses of the chemical products of *L. sativus* are given by König and Harz.

LATHYRUS VENOSUS, Muhl.

Pl. XVI. f. 6b. Pl. XXXIV. f. 1. Pl. XXXV. f. 3.

Testa 130–150 μ thick; endosperm much reduced.

Malpighian. Cells 58–70 μ long. Cuticle somewhat uneven. Cuticularized layer well developed; the light line occurs just below the latter; pores project into the walls below. The walls are striated. Cell-cavity wide at the base, and gradually tapering upward, then becoming constricted. Lateral pores evident. Tschirch and Oesterle have called attention to these in *L. sativus*. A single chromatophore is present in the upper part of the cell-cavity; numerous small grains in the lower part. Cells are pigmented.

Osteosclerid. Length of cells varies from 19–50 μ; intercellular spaces elongated. I-shaped cells with upper and lower bars nearly equal; cells thick-walled, elongated and striated; they contain tannin and protein.

Nutrient. This layer is much compressed. The cells are elongated, thin-walled, with small intercellular spaces. Cells contain an abundance of pigment and tannin.

Nucellus. This layer is compressed and reduced.

Endosperm. Layer is much reduced. Consists of a single layer of thick-walled elongated cells, having a narrow cell-lumen in which small protein grains occur.

Embryo. Cells of the outer row small, having greatly thickened exterior walls; occasionally with some brown pigment. The cells below are thinner walled and more loosely arranged, with intercellular spaces. These cells contain some pigment, protein, and a great deal of starch. The starch grains are rather small. The outer or epidermal layer only, contains protein.

LATHYRUS MARITIMUS, Bigelow.
Pl. XVI. f. 3.

Testa 200–215 μ thick, as in *L. venosus.* Malpighian cells 61–70 μ long and pigmented; cell-cavity large at the base with a more regular outline and less conspicuous lateral pore-canals. Several chromatophores occur in Malpighian cell. The pigmented osteosclerids are thick-walled, 40–60 μ long, marked with longitudinal striae. Nutrient layer differentiated into two parts. Lower part contains more pigment than the upper. Endosperm as in last species. Cells of the embryo contain some pigment and protein grains. Starch grains abundant, 33×14 μ–42×28 μ.

The Malpighian cells of *Lathyrus latifolius*, L., *L. odoratus*, L., *L. sylvestris*, L., and *L. sativus*, L. are irregular on the surface. The light line occurs in the upper third of the cell. In all of these species the cell-cavities contain protein and chromatophores. The Malpighian cells of *L. odoratus* are 110–125 μ long. The testa is 185–200 μ thick. The testa of *L. latifolius* is 95-100 μ thick and the Malpighian cells are 40–45 μ long. In *L. sylvestris* the testa is 180–185 μ thick and the Malpighian cells are 67–80 μ long. The osteosclerids in all of these species are I-shaped, with prominent longitudinal canals. In *L. latifolius* these are 26–30 μ long; in *L. odoratus* about the same; in *L. sylvestris* 22–50 μ long. The nutrient layer in these species does not differ essentially from that of *L. maritimus.* Endosperm is but sparingly developed. In *L. sativus* the aleurone cells are elongated and narrow. Starch grains in the cells of the embryo are spherical or elliptical, variable. The starch grains are large in *L. odoratus.* Compound grains occur occasionally in *L. sativus.* Cell walls are provided with pore-canals.

The starch grains of the different species vary in size as follows: *L. latifolius* 14×19.6–16.8×22–7.4×19.6 μ. *L. odoratus* 16.8×28–11.2×31–16.8×36 μ. *L. sylvestris* 14×26.8–16.8×22.4–8×25. Palisade cells are wanting in all of the species.

PISUM, Tourn.

Testa well developed. Pigment greenish-yellow, or brownish. Nutrient layer well-developed, thin-walled. Endosperm absent or appearing only as a remnant. Sempolowski wrongly called the inner part of the nutrient layer the endosperm. Schleiden and Vogel, and Chalon considered the seed of *P. sativum* as exalbuminous. Pringsheim, in 1848, gave a full account of the structure of the testa in his inaugural thesis. Sempolowski and Harz describe the species in detail. Russow studied only the light line. Tschirch and Oesterle, Tschirch, Hanausek, and other writers on food products, have described the testa and starch. The authors of numerous text-books on botany, like Hoffmeister, Strasburger, Sachs, and others, have given accounts of the starch and protein grains. Mattirolo and Buscalioni describe the anatomical characters of *P. thebaicum*, Willd. and *P. quadratum*. The germination of the common garden pea is described by Marek. Gray and other writers also describe its germination; Dahmen, the anatomy and physiology of the funiculus; Holfert, the nutrient layer; and Pfeiffer, the nature of the funiculus. Numerous chemical analyses have been made of the seed, which have been brought together by Harz, König, Jenkins and Winton; and Likiernik studied some of the special chemical products of the testa.

PISUM SATIVUM, L.

Pl. XXX. f. 1.

Harz and other writers on economic food products have discussed the structure of the testa and cotyledons.

Malpighian. The cells are 96–100 μ long. The thin cuticle is uneven on the surface; the cuticularized layer is but slightly developed; light line occurs just below the enlarged points of the pore-canals; the cell-cavity is wide at the base, somewhat irregular, with one or more chromatophores.

Osteosclerid. The cells are 40–45 μ long, somewhat I-shaped, with small intercellular spaces; the walls are marked with longitudinal pore-canals, which, however, are not so pronounced as in *Lathyrus.*

Nutrient. This layer consists of 10 to 20 rows of elongated, thin-walled cells; in mature specimens this layer is much compressed, especially in the lower part.

Nucellus. Consists of a much compressed layer.

Endosperm. Much reduced and compressed.

Embryo. The epidermal cells of the cotyledons are much smaller than the underlying cells; they contain no starch, or very little; the underlying starch cells are large and irregular, with small intercellular spaces. These cells contain an abundance of starch grains which measure 14×16.8–19.6×25.2–20.4×36.4 μ, each grain with a prominent rift in the center. It is well known that the cotyledons do not expand in germination as they do in *Phaseolus*, *Desmodium*, and many other *Leguminosae.* Palisade cells are uniformly present on the upper side in species where the cotyledons unfold, except in some *Phaseoleae.* In the pea the cells of the inferior and superior sides are similar.

CICER, Tourn.

Harz, and Tschirch and Oesterle have described the structure of the common species. One of the striking features of this species is that the Malpighian cells have irregular lateral walls.

CICER ARIETINUM, L.

Pl. XXIX. f. 2–2c.

Testa 200–225 μ thick. Endosperm reduced or wanting. Starch is present.

Malpighian. Cells vary from 60–70 μ long, very irregular near the hilum, the surface of the seed in this region appearing minutely pubescent. Cuticle not strongly developed; cuticularized layer but slightly developed; the lateral walls very irregular below, thick above; light line in the upper part of the cell. Cell-cavity wide below. Walls color blue with chlor-iodide of zinc.

Osteosclerid. The I-shaped cells 20–33.5 μ long, with large intercellular spaces. Walls, except the middle lamella, color blue with chlor-iodide of zinc, the middle lamella, brownish.

Nutrient. This layer is differentiated into two parts; the upper consists of large cells with comparatively thin walls; the lower of small cells with thin walls.

Embryo. The epidermal cells are much smaller than the underlying parenchyma. The walls of the parenchyma are provided with pore-canals. The cells contain an abundance of spherical or elliptical starch grains and protein. Starch grains color blue with iodine, and the protein grains brownish. Starch grains vary from 16×22–56×10–22×16 μ.

LENS, Tourn.

Harz, in his Samenkunde, and Tschirch and Oesterle describe the microscopical characters of the lentil. The testa in some varieties is variously colored, in others yellowish-brown. Endosperm is reduced to a single row of cells, the aleurone layer. Starch is abundant in the starch layer.

LENS ESCULENTA, Moench.
Pl. XXXIII. f. 3–3b.

Testa 190–200 μ thick, minutely roughened, the endosperm reduced.

Malpighian. Cells 40–45 μ long, slightly irregular on the surface as in the seeds of *Lathyrus;* light line in the upper part of the cell; lower part of the cell dark in color.

Osteosclerid. Cells 20–25 μ long, I-shaped only towards the hilum, otherwise nearly square, separated by wide intercellular spaces.

Nutrient. Parenchyma cells of the nutrient layer thin-walled; lower part more compressed than the upper. This layer contains the pigment.

Endosperm. Wanting except a single row of cells, the aleurone layer.

Embryo. The epidermal cells of the cotyledons small; the cells of the second row larger and containing less starch; the underlying parenchyma relatively thick-walled with pore-canals; the epidermal cells of the superior face are similar to those of the inner surface. Large starch grains abundant, with prominent rifts; they vary from 5×6–11×16–28×11μ. Green pigment is present in the cotyledons, as well as large procambial vessels, which are yellowish in color.

PAPILIONACEAE — Phaseoleae.

APIOS, Moench.

Apios agrees with the other *Phaseoleae* in the poorly developed endosperm, and the presence of starch grains in the embryo.

APIOS TUBEROSA, Moench.

Pl. XIX. f. 4.

Testa 140–145 μ thick.

Malpighian. Cells 52–56 μ long; light line close under the cuticle; cell-cavity large at the base, abruptly contracting near the light line; the cells are colored brown.

Osteosclerid. Cells are 15–18 μ long, I-shaped, separated by a small intercellular space.

Nutrient. This layer is compressed, divided into two parts. Cells of the upper part thin-walled and much larger than the thick-walled cells in the lower part.

Endosperm. Reduced to a single row, the aleurone layer.

Embryo. The epidermal cells are smaller than the underlying parenchyma, which has small intercellular spaces. All of the cells contain an abundance of small starch grains. They are much smaller than in allied genera. Aleurone grains are also abundant.

MUCUNA, Adans.

The structure of the seed-coat is by no means uniform in the different species of the genus. In *Mucuna urens*, studied by the writer, the brown Malpighian cells are long, and coriaceous. The cuticle is also well defined. The nutrient layer is well developed and not compressed as in many other genera of *Leguminosae*. The structure of the entire seed indicates adaptation for dissemination by water. The Malpighian cells of *Mucuna pruriens* are less coriaceous, and the cells of the nutrient layer are more compressed. Endosperm reduced. Cells of the cotyledons contain an abundance of large starch grains.

MUCUNA PRURIENS, DC.

Pl. XXIII. f. 4. Pl. XXVII. f. 1-1d.

Malpighian. In the region of the hilum there is a double row of cells; the light line occurs under the cuticle, and a second indistinct line near the base of the cell.

Osteosclerid. In the hilar region the I-shaped cells are much like the spongy parenchyma of the nutrient layer, elsewhere greatly elongated, with large intercellular spaces.

Nutrient. Layer divided into two parts; the cells of the upper part with thicker walls, and larger than those of the lower.

Endosperm. Sparingly developed.

Embryo. The epidermal cells have thick exterior walls, and are much smaller than the underlying cells; palisade cells wanting. The cells contain large starch grains as well as aleurone grains.

PHASEOLUS, Tourn.

Many of the cultivated species have been studied because of their economic importance. Schleiden and Vogel, Chalon, Harz, Nadelmann, Tschirch and Oesterle, Tschirch, Nobbe, Tautphoes, Le Monnier, Hartig, Pringsheim, Sachs, Likiernik, Brongniart, Mattirolo and Buscalioni, Haberlandt, Löhr, Strasburger, Huss, Schröder, Mirbel, Strandmark, Hanausek, and the writer, as well as numerous others, have given accounts of the seed or parts of it in this genus.

Testa variously colored, brown, purple, red, and whitish, usually well-developed. The osteosclerids are usually I-shaped, with large intercellular spaces, although in *P. vulgaris* the cells are uniformly prismatic, thinner-walled, and contain a single one or a pair of large calcic oxalate crystals; these sometimes also occur in *P. multiflorus* but in this species the layer has intercellular spaces. These crystals do not occur in *P. lunatus* or *P. perennis* nor were they found by Haberlandt or Harz in *P. inamoenus* and *P. Mungo.* Nor does Harz record crystals in *P. acutifolius*, nor Strandmark in *P. ornithopus.* The nutrient layer is much compressed, and in the colored species and varieties it is abundantly pigmented. The mycotic cells occur in *P. multiflorus*, *P. vulgaris*, and

P. inamoenus. Haberlandt speaks of these as "verfilzten Zellen." Endosperm is but sparingly developed, usually consisting of a row of tabular cells, the aleurone, followed by one or more rows of thick-walled cells. The nucellus is reduced. The embryo contains fat, protein, and starch. Poorly developed palisade cells, scarcely to be distinguished from the parenchyma, occur on the upper face of the cotyledon in some species, but are usually absent. For the numerous chemical analyses, Harz, König, and Jenkins and Winton should be consulted.

PHASEOLUS PERENNIS, Walt. (*P. polystachyus*, L., BSP.) *Pl. XXI. f. 5–5b.*

Brown testa and endosperm 132–265 μ thick. The upper part of the nutrient layer variable.

Malpighian. Cells are 109–115 μ long. Cuticle slightly uneven; cuticularized layer poorly developed; several pores project into the walls from the cuticularized layer, to the light line or in some cases much beyond; the light line is narrow and occurs under the cuticularized layer. Cell-cavity is large at the base, gradually tapering upward, irregular in outline; small remnants of protoplasm occur in the cavity, and also considerable brown pigment and tannin.

Osteosclerid. The cells are thick-walled, 14 μ long, I-shaped, with large elongated intercellular spaces.

Nutrient. This layer is compressed and differentiated into two parts; cells of the upper part smaller, elongated and thinner-walled; in the hilar region it consists of star-shaped parenchyma with large intercellular spaces. Cells of the lower part are larger but variable. They contain a large amount of pigment and tannin.

Endosperm. Laterally a single row of cells, but in the micropylar region more strongly developed. The internal part of the endosperm consists of thick-walled elongated cells. These carry some protein grains.

Embryo. First row of cells smaller; exterior walls thickened; lateral walls are thinner; cells below the epidermis larger and more loosely arranged, with intercellular spaces in the angles. Upper portion of the cotyledon in germination with small epidermal cells much as in the lower part, followed by ordinary parenchyma. Procambial vessels not lignified. Cells contain an abundance of fat, protein, and large, stratified starch grains.

PHASEOLUS MULTIFLORUS, Willd.

Pl. XXI. f. 2–2g.

A full account of this seed is given by Mattirolo and Buscalioni. Tschirch and Oesterle, Harz, Holfert, and Haberlandt also treat the anatomy of the seed briefly. A general account is also given by Lubbock, and by Sachs, who studied its germination.

Holfert distinguishes five layers of the testa: (1) Malpighian, (2) osteosclerid, (3) obliterated nutrient layer, (4) star-shaped parenchyma, (5) obliterated star-shaped parenchyma (verfilzt). The testa is spotted, much larger than in *P. perennis*, laterally 580 μ thick, towards the edges 770 μ thick.

Malpighian. The cells are 84 μ long. Cuticle smooth; cuticularized layer not strongly developed; light line runs close under the latter; pores project into the wall below the light line. Cell-cavity large at the base, narrowed rather abruptly above. Walls of some of the cells as well as the cavity contain a bluish pigment, especially in the lower portion. The walls, cuticularized layer, and light line color blue with chlor-iodide of zinc.

Osteosclerid. Cell-walls thickened, longitudinally striated. Cells I-shaped, with elongated intercellular spaces. Cells contain some pigment.

Nutrient. Layer differentiated into two parts; cells of the upper portion thin-walled, loosely arranged, with numerous intercellular spaces; but little pigment present. Cells of the lower part narrower, thicker-walled, with more pigment, and tannin. Vascular elements occur in this part of the nutrient layer; these are also pigmented. The walls of the vessels give the reaction for lignin. The walls of the other cells of the nutrient layer color blue with chlor-iodide of zinc.

Mycotic. In cross-section the cells are closely packed and would pass for ordinary parenchyma; a tangential section, however, shows that the cells are elongated, somewhat star-shaped, and thick-walled. Cells strikingly resemble hyphae of fungi. These cells contain some protein.

Endosperm. Sparingly developed, usually a single row of cells, the aleurone layer, followed by thick-walled elongated cells with a small lumen. Cells contain fat and protein.

Embryo. Cells of the first row with thickened exterior walls; cells below more loosely arranged, larger than the epidermal cells, and with intercellular spaces in the angles; the cell-walls are thickened and connected with the adjoining cells by conspicuous pore-canals. Cells contain an abundance of protein, fat, and large starch grains with very evident stratification.

PHASEOLUS LUNATUS, L.

Pl. XXI. f. 1–1d.

The testa of this species has been studied by Haberlandt and Harz. Variable in thickness in the cultivated varieties, but much thinner than in *P. multiflorus*, 180–184 μ thick. Malpighian cells 60–61 μ long; cell-cavity wide at base and rather abruptly narrowed; light line close under the cuticle. Osteosclerids thick-walled, elongated, and somewhat funnel-shaped, intercellular spaces round or elongated. Nutrient layer consists of three to six rows of compressed cells, with vascular elements in the lower part. Cells in the outer row of the embryo are smaller; exterior walls thickened; cells below larger and more loosely arranged, and elongated, with intercellular spaces. The inner part of the cotyledon with parenchyma cells like the superior face. Cells of the cotyledons contain a great deal of starch, the large grains generally with longitudinal rifts. Also an abundance of protein and some fat.

STROPHOSTYLES, Ell. (*Phaseolus*, Kew Index.)

Testa variable, smooth or covered with hairs, otherwise much as in *Phaseolus*.

STROPHOSTYLES ANGULOSA, Ell. (*P. diversifolius*, Pers. Kew Index. *S. helvola*, L., Britton.)

Pl. XXI. f. 4.

Testa, including hairs, 332 μ thick.

Malpighian. Layer covered by a coat of brown hairs.

Cells thin-walled, usually as long as broad, obtuse, 106 μ long. Cell-cavity wide at the base, gradually tapering upward.

Osteosclerid. Thick-walled cells 19 μ long; intercellular spaces nearly square. Cells with a brown pigment.

Nutrient. Layer differentiated into two parts. In the upper part the cells are thin-walled and elongated, with large intercellular spaces; in the lower part they are smaller and thicker-walled.

Endosperm. The endosperm is reduced to the aleurone layer.

Embryo. The cells of the first row on the inner face are much smaller than the cells below. Cells of the second row are larger and compactly arranged; those of the interior are larger and more loosely arranged. The epidermal cells as well as those of the second row contain little or no starch. Walls of the cells of interior part of the cotyledons with pore-canals. The epidermal cells of the superior surface of the cotyledons are elongated, thick-walled, and contain no starch; palisade cells absent. Cells contain elliptical, spherical, or very irregular starch grains, aleurone grains, and fat.

STROPHOSTYLES PAUCIFLORUS, Watson. (*S. pauciflora*, Benth. Watson. *Phaseolus pauciflorus*, Benth. Kew Index.) *Pl. XXI. f. 3.*

Testa and endosperm 400–420 μ thick. Cuticle pronounced, covered with hairs; light line runs close under the cuticle; cell-cavity larger than in *S. angulosa;* cells contain an abundance of pigment and tannin. The intercellular spaces of the osteosclerids are elongated; the bars of the I-shaped cells are equal. The cells contain a great deal of tannin and pigment. Nutrient layer is as unequally developed as in the last species, with an abundance of vessels in the lower portion. Endosperm sparingly developed. The first row of cells, the aleurone layer, with thick walls, containing protein. Cells of superior face similar to those of inferior surface.

VIGNA, Savi.

Testa nearly colorless or pigmented, well-developed. The Malpighian cells are elongated; the thinner portions of the testa of *V. monachalis*, according to Harz, measure 22–24 μ long, and 33–90 μ in the hilar region. Osteosclerids are 13–24 μ long. Endosperm usually wanting. Embryo contains an abundance of starch and protein. The germination of *Vigna lutea*, Gray and *V. vexillata*, Benth. were studied by Lubbock.

VIGNA CATJANG, Walp. (*V. sinensis*, L., Endl.)

Pl. XXXIII. f. 1–1c. Pl. XXXIV. f. 3. Pl. XXXV. f. 9–10.

This species has been studied by Mattirolo and Buscalioni, Harz, Tschirch and Oesterle, and the writer.

Malpighian. Cells 55–57 μ long, nearly colorless in some varieties, in others with a bluish pigment; light line close under the poorly developed cuticularized layer; cell-cavity relatively large; an abundance of tannin present.

Osteosclerid. Cells are I-shaped and somewhat widely separated by the elongated intercellular spaces.

Nutrient. The cells of this layer have thin walls and are much compressed.

Endosperm. This is reduced to a single row of cells, the aleurone layer.

Embryo. The epidermal cells are smaller than underlying parenchyma, and contain only protein. The cells of the second row are somewhat larger, containing starch; intercellular spaces at the angles of the cells. The parenchyma below consists of large cells, their walls with pore-canals; they contain an abundance of large and small spherical or somewhat elliptical starch grains. Aleurone grains with one globoid. The nucleus may be readily made out when treated with iodine. Palisade cells are absent.

VIGNA GLABRA, Savi.

Pl. XX. f. 3.

Testa spotted, 140–150 μ thick. Malpighian cells are 74–80 μ long. The light line occurs close under the cuticle. Pore-canals extend below the light line; the cell-cavity contracts rather abruptly. The osteosclerids are of the usual type, I-shaped. The nutrient layer consists of five or more rows of cells. The mycotic layer is very narrow. The endosperm is much reduced, consisting of the well-defined aleurone layer. Epidermal cells of the inner face of the cotyledons much smaller than the underlying parenchyma cells, containing no starch; second row of cells intermediate between the epidermal cells and the parenchyma below. Palisade parenchyma wanting. Procambial bundles large, yellowish in color. Starch grains vary from 17.6×28–141×6.6–28×42 μ.

DOLICHOS, L.

Studies of the genus have been made by Godfrin, Schleiden and Vogel, Harz, Haberlandt, and Mattirolo and Buscalioni. All of the writers studied forms of *D. Lablab*. Schleiden and Vogel as well as Chalon state that the seeds are exalbuminous, but Harz found endosperm sparingly present. The seeds of the species are used in tropical countries like the seeds of *Vigna* and the Soy bean.

DOLICHOS LABLAB, L.

Pl. XXXIII. f. 4.

Malpighian. Cells 125–135 μ long; walls strongly thickened; light line close under the cuticle; cuticularized layer but slightly developed; pore-canals extend considerably beyond the light line. Several chromatophores are present in the cavity.

Osteosclerid. Cells large, 40–52 μ long; walls not strongly thickened. Large intercellular spaces separate adjoining cells.

Nutrient. Layer much compressed; cells with comparatively thin walls.

Endosperm. Sparingly present, reduced to the aleurone layer.

Embryo. Epidermal cells much smaller than the parenchyma; cells of the second row larger than those of the first row, but smaller than the parenchyma cells.

Epidermal cells contain a number of aleurone grains but starch is absent; the parenchyma below has an abundance of starch. The grains are similar to those of *Vigna*. They vary from 10 to 21 μ, occasionally some 35–40 μ. The epidermal cells of the superior face of the cotyledon are much smaller than the underlying parenchyma; they contain no starch, but well-developed aleurone grains. Palisade parenchyma wanting. The third row of parenchyma cells of the inferior face longer than broad. Procambial vessels yellowish.

CENTROSEMA, Benth. (*Bradburya*, Raf.)

Testa smooth. Endosperm sparingly developed. Cotyledons with thick-walled, stratified cells, the reserve cellulose. Chalon found endosperm present.

CENTROSEMA VIRGINIANUM, Benth. (*B. virginiana*, L., Kze.) *Pl. XIX. f. 3. 5.*

Testa 150 μ, towards the ends 250 μ or more thick.

Malpighian. Cells nearly colorless, 56 μ long; cuticle an even layer; cuticularized layer inconspicuous; light line just below the latter; several pores extending into the wall below the light line. Cell-cavity large at the base, abruptly con tracted near the light line, containing one or more chromatophores in the cavity. The cell-cavity is smaller in the upper third of the cells and large near the base.

Osteosclerids. The thick-walled cells 14 μ long, toward the hilum 60–65 μ long. I-shaped cells with upper and lower bars nearly equal. Intercellular spaces elongated.

Nutrient. This layer is composed of from three to twelve rows of thin-walled cells. Cells in the lower portion carry much more pigment and tannin than the upper.

Endosperm. The aleurone cells are continuous, followed by one or two rows of mucilaginous endosperm. The internal part of the endosperm consists of thick-walled elongated cells with a narrow lumen. Cells contain protein.

Embryo. Cells of the first row continuous and isodiametric, with exterior walls thickened and stratified. Cells below are larger, the stratified walls greatly thickened and provided with pore-canals. Although the germination of this species has not been studied, the thick-walled cells are without doubt analogous to the reserve cellulose in the cotyledons of other plants. The walls respond quickly to the test for cellulose, and are easily soluble in sulphuric acid. The cells contain no starch, but an abundance of fat and protein. Palisade cells wanting.

CLITORIA, L.

Schleiden and Vogel give a brief account of *Clitoria Ternatea*, L., in which they found thick-walled cells in the cotyledons. This is not characteristic in all the species. Chalon indicated the presence of endosperm in the genus. In both of our species endosperm is present. Schleiden and Vogel expressed some doubt with reference to endosperm. The general characters of the seed and the germination of the above species are given by Lubbock. Germination studies of *C. Mariana* were made by Holm. The raphe is absent. The chalaza occurs in the thickened part of the testa. The micropyle is adjacent to the hilum.

CLITORIA MARIANA, L.

Pl. XVIII. f. 4. Pl. XX. f. 1.

Testa and endosperm 230–235 μ thick, the former brown.

Malpighian. Cells are 70–74 μ long. Cuticle somewhat uneven; the narrow light line occurs close under the cuticle; cavity wide at the base, becoming very narrow in the middle. Pigment irregularly distributed — portions are deeply colored.

Osteosclerid. Cells are 22.4 μ long, thick-walled and elongated; cavity very much reduced; bars of the I-shaped cells nearly equal; intercellular space narrow and elongated. Cells contain pigment and tannin.

Nutrient. Layer differentiated into two parts. The cells of the upper part are thinner-walled, and contain less pigment than those of the lower portion. Vascular elements occur in the lower part of the layer.

Endosperm. The large aleurone cells are nearly isodiametric and continuous, thick-walled, containing protein. The aleurone layer is followed by the mucilaginous reserve cellulose. It is somewhat variable as to thickness; the internal layer consists of thick-walled, elongated cells, with a narrow lumen. The cells contain protein.

Embryo. Cells of the first row are smaller and form a continuous layer; epidermal cells of superior face like those of inner surface, exterior walls thickened; interior cells with thicker walls and provided with pore-canals. Palisade cells wanting. I do not hesitate to consider this reserve cellulose, because of its ready solubility. It is true that the crucial test would be a study of it during germination.

CLITORIA TERNATEA, L.

Testa and endosperm 415 μ in thickness. Pigment and tannin abundant in the Malpighian and lower portion of the nutrient layers. Malpighian cells 140 μ long, each cell with one or more chromatophores. Osteosclerids united or more or less separated. The I-shaped cells thick-walled. The cells of the lower part of the nutrient layer thicker-walled than those of the upper part. The aleurone layer of the endosperm thick-walled; the remainder as in *C. Mariana.* The first row of cells of embryo nearly isodiametric. The cells below are elongated and more loosely arranged. Cell-walls comparatively thin. All of the cells contain fat and protein but no starch.

AMPHICARPAEA, L. (*Falcata*, Gmel.)

Both of the species which I have studied contain endosperm, remnants of the nucellus, and an abundance of pigment and tannin. The osteosclerids are striated. Embryo contains fat and protein but no starch.

AMPHICARPAEA MONOICA, Nutt. (*F. comosa*, L., Kuntze.)
Pl. XVII. f. 3.

Testa and endosperm 235 μ thick. An abundance of pigment in the Malpighian cells and nutrient layer. The species has been studied by Miss Schively, but her account is quite inaccurate in details. The light line, which is well-developed, is not shown in the figures nor described.

Malpighian. Cells 120–150 μ long, brown. Cuticle somewhat uneven; cuticularized layer not pronounced; light line below the cuticularized layer; several pores project into the walls below the light line. The cavity is wide at the base, gradually tapering upward, and is very narrow in the light line region.

Osteosclerid. Cells 40–60 μ long, well-developed, longitudinally striated, especially in the hilar region. I-shaped cells with the upper and lower cross-bars nearly equal. Cells contain some tannin and pigment.

Nutrient. This layer is differentiated into two parts. The upper portion consists of larger thin-walled cells. Cells in the lower part thicker-walled and containing some pigment. The vascular elements occur in this region.

Nucellus. This is much compressed.

Endosperm. As in all other genera of the tribe *Phaseoleae*, the endosperm is greatly reduced, consisting of a single row of cells, the aleurone layer, having very thick walls. The contents of the cells consist of granular protein.

Embryo. The exterior walls of the first or epidermal cells are thickened. The cells below are larger and more loosely arranged. All of the cells contain fat and protein.

AMPHICARPAEA PITCHERI, T. & G. (*Falcata Pitcheri*, T. & G., Kze.)

The anatomy of this species has been studied by Schively, and its germination by Hitchcock. Malpighian cells with a slightly irregular cuticle; cuticularized layer but slightly developed; the light line occurs close under the cuticularized layer; cells with an abundance of pigment which is soluble in water. Osteosclerids I-shaped, long, with a large intercellular space. Nutrient layer and endosperm much compressed. Epidermal cells of the cotyledons much smaller than the underlying parenchyma. Exterior walls much thicker than the lateral ones. The second row of parenchyma cells intermediate between the epidermis and the parenchyma of the inferior. Large aleurone grains imbedded in the oil plasma. Starch absent. Palisade cells wanting. — (Muscatine, Reppert, — Washington, D. C., Steele.)

GALACTIA, P. Br.

Endosperm reduced. Anatomically the genus shows close relationship to *Rhynchosia*. The germination of *G. glabella*, Michx., has been studied by Lubbock.

GALACTIA GLABELLA, Michx. (*G. regularis*, L., BSP.)

The yellowish testa and endosperm vary from 149–166 μ in thickness.

Malpighian. The cells are 70 μ long. Cuticle somewhat uneven; light line just under the cuticularized layer; cell-cavity large at the base, gradually tapering upward, narrow in the light line region.

Osteosclerid. The I-shaped cells thick-walled, 14–30 μ long; bars nearly equal except in the hilar region. Intercellular spaces elongated. Cells contain some pigment and remnants of the protoplasm.

Nutrient. Differentiated into two portions; in parts of the testa only one layer is evident; cells of the upper part are thick-walled and contain more pigment than the lower.

Mycotic. In some portions of the seed this layer is well developed and consists of thick-walled cells shorter than those of the nutrient layer. The cells contain remnants of protoplasm.

Endosperm. The thick-walled cells of the aleurone layer contain protein. The mucilaginous reserve cellulose is variable in thickness and not usually well developed; the internal layer consists of thick-walled, elongated cells with small cavity. Cells contain some protein matter.

Embryo. Epidermal cells are small; cells of the inner surface nearly isodiametric; epidermal cells on the superior face somewhat longer than wide; the exterior walls thickened. Walls of parenchyma cells thickened, with numerous pore-canals, the cells of the second row smaller than the underlying parenchyma. Cells contain an abundance of starch, fat, and protein grains, except the epidermal cells, where starch is absent. Palisade parenchyma absent.

GALACTIA PILOSA, Ell. (*G. volubilis*, L., Britton.)
Pl. XVII. f. 2.

This species does not differ essentially from *G. glabella*. Light line close to the cuticle. Nutrient layer divided into two parts. The endosperm consists of a single row of cells, the aleurone layer; the large parenchyma cells are thick-walled and contain large stratified starch grains.

GLYCINE, L.

The structure of the testa was studied by Haberlandt, Harz (**2**: 693), and Tschirch and Oesterle. The common Soy bean runs into numerous varieties. Starch is absent. An abundance of fat and aleurone. Endosperm is sparingly developed.

GLYCINE HISPIDA, Maxim.
Pl. XXXII. f. 9–9b. Pl. XXXIII. f. 5–6.

Malpighian. Cells 50–60 μ long, the longest in the hilar region. Light line situated somewhat above the middle; cavity large at the base, gradually tapering upward. In dark colored varieties these cells are abundantly pigmented.

Osteosclerid. Cells 27–50 μ long, I-shaped. In hilar region nearly as long as the Malpighian cells, with large intercellular spaces.

Nutrient. The layer is much compressed, consisting of two parts: the outer, of larger cells more loosely arranged; the inner, of thin-walled and smaller cells. The cells of the nutrient layer are pigmented.

Endosperm. Endosperm is sparingly developed, the aleurone cells are large and contain protein. The remainder consists of thick-walled cells which contain small amounts of protein.

Embryo. The epidermal cells are smaller; exterior walls thickened, otherwise the walls of the cotyledons are thin. The cells underneath the epidermis of the inner face are larger, but much shorter than the underlying parenchyma; the third row of cells long; several rows of palisade cells on the superior face. The embryo contains no starch, but an abundance of fat and protein. The aleurone grains are imbedded in the oil plasma.

RHYNCHOSIA, Lour.

Endosperm reduced. Chalon states that the seeds are exalbuminous. The cotyledons contain an abundance of starch, the grains of variable size. *R. glandulosa* was studied by Schleiden and Vogel.

RHYNCHOSIA LATIFOLIA, Nutt.
Pl. XVII. f. 4.

Testa and endosperm 150–166 μ thick. The osteosclerids contain a great deal of pigment.

Malpighian. Cells 72–74 μ long, with very little pigment.

Cuticle well-developed; the narrow light line occurs below the cuticularized layer; cell-cavity wide at the base with a somewhat irregular outline, with one or more chromatophores and remnants of the protoplasm.

Osteosclerids. The thick-walled I-shaped cells 19–20 μ long. Contents of cells and walls are brown in color.

Nutrient. Differentiated into two parts; cells of the upper part thin-walled and larger than those of the lower portion. All of the cells contain pigment and tannin.

Endosperm. This usually consists of a single row of thick-walled, elongated cells. Cell-cavity contains protein matter.

Embryo. Epidermal cells much smaller than those below; exterior walls thickened; cells below elongated, with small intercellular spaces at the angles, the somewhat thickened walls with pore-canals. The cells contain an abundance of protein, some fat, and starch grains of various sizes. The starch grains color blue with iodine, and the walls, with chlor-iodine of zinc. — (McDonald Co., Missouri, Bush, Mo. Bot. Gard.)

CAESALPINIEAE — Bauhinieae.

CERCIS, L.

Testa smooth and hard with strongly developed mucilaginous endosperm. Systematic works indicate the presence of endosperm. Schleiden and Vogel, and Chalon recorded it in *C. siliquastrum.* The mucilaginous reserve cellulose of this species was described by Nadelmann. Germination studies were made by Lubbock and Tubeuf.

CERCIS CANADENSIS, L.

Pl. XVII. f. 1–1b.

Testa and endosperm laterally 664–670 μ thick, toward the edges only 290 μ. Testa 174 μ laterally, on the ends 207 μ thick. Cotyledons narrow, 464 μ across. Chalon studied the species with reference to endosperm.

Malpighian. This layer nearly colorless; the chromatophores occur in the upper part of the cell. Cuticle is an even layer, followed by a narrow but well marked bright, colorless, cuticularized zone; the narrow upper light line extends across the cell below the cuticularized layer; the upper part of the cell-cavity is widened just above the lower light line; part of the cell above the upper light line separates readily from the remainder of the cell-wall. Below the enlarged upper part of the cell-cavity the Malpighian cell is more refractive than in the lower part. Cells contain in addition to the chromatophores numerous small protoplasmic granules.

Osteosclerid. Thick-walled cells not markedly different from the cells of the nutrient layer. Small intercellular spaces, adjacent to the Malpighian cells.

Nutrient. Layer is differentiated into two parts; thick-walled cells of the upper portion somewhat elongated or nearly isodiametric, with pore-canals, containing but little pigment; cells of the lower portion elongated, thick-walled, having small pore-canals.

Endosperm. This is copious, cartilaginous when dry, mucilaginous and nearly colorless when moistened; the cells of the aleurone layer are thick-walled and contain protein; layer below of variable thickness, consisting of ten or more rows of thick-walled, mucilaginous cells, with prominent pore-canals. The internal part consists of thick-walled elongated cells with a narrow cell-cavity, or some cells with thinner walls, containing remnants of protoplasm. Walls differentiated into three parts; the secondary and tertiary layers color blue with chlor-iodide of zinc; the primary wall is thin and not affected by this reagent.

Embryo. The epidermal cells are nearly isodiametric, with exterior walls thickened; the cells below are longer and more loosely arranged, with small intercellular spaces; palisade cells on the inferior face of the cotyledons; all of the cells contain protein and fat but no starch. Walls color blue with chlor-iodide of zinc.

CAESALPINIEAE — Cassieae.

CASSIA, Tourn.

Quite a large number of the species have been studied, but more especially the medicinal species. Schleiden and Vogel studied *C. stipulacea*, Soland., *C. Fistula*, L., *C. speciosa*, Schrad., and *C. reniformis*, G. Don; the latter was also studied by Pringsheim. Chalon studied seventeen species, but only with reference to endosperm, except *C. Fistula*, L., of which the Malpighian cells as well are described. His figures are somewhat diagrammatic. The height of these cells is simply compared with some other *Leguminosae* studied by him. Nadelmann studied the development and the mucilaginous endosperm of *C. Fistula*, L. and *C. corymbosa*, Lam. Tschirch and Oesterle studied *C. angustifolia*, Vahl. The mucilaginous endosperm of *Cassia* is also described by Tschirch in his Angewandte Pflanzenanatomie. Lubbock has studied the germination of *C. Fistula* L., *C. circinata*, Benth., and *C. obovata*, Coll. De Candolle's germination studies agree with those of Hitchcock and Holm. So far as studied, all the species of the genus agree in the mucilaginous endosperm, the sclerotic nutrient layer, and the but slightly differentiated osteosclerids. A second osteosclerid layer below the nutrient is followed by several rows of thin-walled cells — the inner testa. Starch is absent from the embryo, but there is an abundance of protein and fat.

CASSIA CHAMAECRISTA, L.

Pl. XX. f. 4–4e.

Testa and endosperm measure 160–265 μ in the narrow parts of the seed; in the wider parts, 415 μ. Cotyledons 400–415 μ across.

Malpighian. Cells 44.8 μ long. Cuticle thickened, brownish, followed by a wide cuticularized layer; the narrow light line occurs under the cuticularized layer; the upper third of the cell is more refractive; several pore-canals project into the walls beyond the wide refractive portion. The cell-cavity is wide at the base, gradually tapering upward, enlarging at the upper light line. The cells contain a large chromatophore with some protein and a little coloring matter.

Osteosclerid. The thick-walled cells are nearly colorless, 84 μ long, with a rather large intercellular space between adjacent cells; occasionally these cells are not essentially different from those of the nutrient layer.

Nutrient. Consists of thick-walled sclerotic parenchyma.

Walls with radiating pore-canals. The walls color blue with chlor-iodide of zinc.

Endosperm. The aleurone cells are thick-walled and contain small protein grains. They are followed by the thick-walled mucilaginous reserve cellulose. Reactions of the cell-walls similar to those of *Cercis canadensis.*

Embryo. First row of cells small, nearly isodiametric; cells below elongated, with small intercellular spaces; the embryo contains no starch but there is an abundance of fat and protein; palisade cells on the superior face of the cotyledons.

CASSIA NICTITANS, L.

Pl. XX. f. 2. Pl. XXXIV. f. 5.

Testa and endosperm 165–350 μ wide. Malpighian cells 50–53 μ long; the upper part of the cell contains more pigment; light lines as in *C. Chamaecrista.* The thick-walled osteosclerids are but slightly differentiated from the cells of the nutrient layer, 10–12 μ long. Nutrient layer well-developed, cells thick-walled and sclerotic, containing a brown pigment. The inner testa as in other members of the genus. The endosperm as in *C. Chamaecrista,* differentiated into aleurone, middle mucilaginous reserve cellulose, and internal layers. Embryo as in the last species. — (St. Louis, Mo., Pammel. — Ithaca, N. Y., Stewart.)

CASSIA MARYLANDICA, L.

Pl. XX. 5-5b.

Chalon studied the species with reference to endosperm. Testa and endosperm 500–530 μ thick. Malpighian cells 92.4 μ long, more deeply colored in the lower part. Cuticle and cuticularized layer well developed; the narrow light line occurs close under the cuticularized layer; the second light line is wider, and occurs 40 μ from the cuticle, although its position is somewhat variable. Pore-canals in two series, one in the light line region and a second below. Osteosclerids 20–22 μ long; walls plainly differentiated into two parts; the cell-cavity almost obliterated in some cells. The cells are as a rule I-shaped, containing pigment and tannin. Cells of the nutrient layer are sclerotic; the walls are brown, while the cell-cavities are much deeper in color. The first layer of the inner testa is made up of osteosclerids; followed by several rows of thin-walled parenchyma. Endosperm and embryo similar to *C. nictitans* and *C. Chamaecrista.* — (Cult. Mo. Bot. Gard., St. Louis, Pammel.)

CAESALPINIEAE — Eucaesalpinieae.

HOFFMANSEGGIA, Cav.

Chalon found endosperm in *H. falcaria*, Cav.; detailed studies, however, were not made. The character of the Malpighian cells shows that the genus is closely related to *Gymnocladus* and *Gleditschia.* The cotyledons also agree with these genera. In both of our species the endosperm is cartilaginous.

HOFFMANSEGGIA JAMESII, T. & G.

Pl. XIX. f. 2–2b.

Testa and endosperm are 225–250 μ thick; the cotyledons, 996 μ across.

Malpighian. The cells are 64.4 μ long. Cuticle is smooth; cuticularized layer well developed; the narrow upper light line occurs under the cuticularized layer; a broad and refractive zone occupies one-third of the upper part of the cell. The cell-cavity is wide at the base, gradually tapering upward. Pore-canals several, extending beyond the upper light line. The canals are enlarged in the upper part of the cell, giving this part of the cell a beaded appearance. Cells contain a yellow pigment, and numerous small grains consisting of protein.

Osteosclerid. Cells of the layer widely separated, with large intercellular spaces. Walls thickened, color blue with chlor-iodide of zinc.

Nutrient. This layer is not strongly developed. Cells are elongated, thick-walled but scarcely sclerotic as in *Cassia.* Its structure approaches *Apios.*

Endosperm. The aleurone layer consists of thick-walled cells, containing protein; the cells below are thick-walled with large pore-canals, and likewise contain protein. Internal layer with thick-walled cells and a small lumen. Usually only one layer of cells evident in the endosperm.

Embryo. First row of cells smaller; exterior walls thickened. Cells below much larger, thinner-walled, and more loosely arranged; palisade parenchyma on the inner face. The epidermal cells of superior face do not differ essentially from those of the lower. All of the cells contain an abundance of fat, and protein but no starch. All of the cell-walls color blue with chlor-iodide of zinc.

HOFFMANSEGGIA DREPANOCARPA, A. Gray.

In this species the testa and endosperm are 300 μ thick. Malpighian cells 50 μ long. The wide light line in upper part of layer is narrower than in *H. Jamesii.* Cells of the nutrient layer much less thickened than in *Cassia.* Aleurone layer forms a continuous envelope around the mucilaginous endosperm. Cell-walls of the reserve tissue differentiated into primary, secondary, and tertiary thickenings. Endosperm is cartilaginous but becomes mucilaginous on the addition of water. The first row of cells of the cotyledons have their exterior walls thickened. Cells below larger and more loosely arranged, containing fat and protein.

GYMNOCLADUS, Lam.

Seeds with smooth and hard testa. A large amount of cartilaginous endosperm. Cells of the sclerotic parenchyma of the nutrient layer in numerous rows. Inner testa as in *Gleditschia.* Cotyledons agree with those of *Gleditschia* and *Cassia.* My study of *G. canadensis,* made in 1885, was evidently overlooked by Nadelmann, who has given an excellent supplementary account of the structure of the coffee bean.

GYMNOCLADUS CANADENSIS, Lam. (*G. dioica,* L., Koch.)
Pl. XXV. f. 1–1g.

The testa is 230–235 μ thick. Endosperm variable in thickness but easily made out with the naked eye. Histologically it shows a close relationship to *Gleditschia.*

Malpighian. Cells 192–196 μ long with a wide, colorless, cross-striated band in the upper part; the prominent cuticularized layer occurs below the cuticle. Below the cross-striated zone the pore-canals enlarge; the light line occurs above the middle. The cells contain some pigment.

Osteosclerid. Thick-walled cells are 30–35 μ long; the upper and lower cross-bars nearly equal; small intercellular spaces between the bars.

Nutrient. Consists of thick-walled sclerotic cells; the walls of the outer part are darker colored than the interior.

Inner integument. The inner coat is much compressed and can be made out only on the addition of chloral hydrate to the section. It consists of a row of quadrangular cells followed by thinner-walled osteosclerid-like cells and ducts.

Nucellus. The nucellus is much compressed and consists of elongated cells with granular contents.

Endosperm. The cartilaginous endosperm consists of thick-walled cells which on the addition of water are converted into mucilage; the water causes the secondary walls soon after to become dissolved, leaving large intercellular spaces. The lower part of the endosperm consists of cells which are smaller, with less thickened walls. This is much compressed.

Embryo. The cells of the first row are elongated and smaller than the underlying. Numerous procambial vessels in the cotyledons, and, in some cases, well-formed spiral ducts. Palisade cells absent. Cells contain fat and protein, but no starch.

GLEDITSCHIA, Clayton. (*Gleditsia*, L.)

Because of the more easily accessible material, several species have been studied. Schleiden and Vogel, Huss, Harz, and Chalon made an examination of the following species: *G. caspica*, Desf., *G. triacanthos, L.*, *G. latisiliqua*, Lodd., *G. indica*, Pers., and *G. macracantha*, Desf., but only with reference to endosperm. Nadelmann gives a very full account of the mucilaginous endosperm of *G. caspica*.

All of the species are characterized by having a smooth hard testa; copious cartilaginous endosperm which on the addition of water becomes mucilaginous; sclerotic parenchyma; nutrient layer strongly developed and, as in *Gymnocladus*, an inner testa occurs. Cotyledons agree with *Cassia* and *Gymnocla-*

dus. Moser's chemical analyses of *G. glabra* are given by Harz and König. The seed contains 2.96 per cent. of fat; 20.94 of protein; and 51.68 of nitrogen-free extract, 21.24 of this being dextrose, and 41 converted by sulphuric acid into sugar.

GLEDITSCHIA TRIACANTHOS, L.

Pl. XIX f. 1–1b.

Harz, and Schleiden and Vogel give short accounts of the structure of the testa and the endosperm. Testa and endosperm 1135–1160 μ thick; the endosperm varies from 600–675 μ thick; the sclerotic nutrient layer is 300 μ thick; osteosclerids 25.2 μ long.

Malpighian. Cuticle thick; the straw-colored cuticularized layer is followed by the narrow light line; a wide refractive zone occurs below the cuticularized layer, with no evident pore-canals, which stains readily with haematoxylin. Below the wide refractive band the pore-canals are enlarged, then become narrow and project into the walls for some distance. Cells contain protoplasmic remnants and some coloring matter. The narrow light line is not stained with haematoxylin; the wide refractive zone stains, but less deeply than the remainder of the wall, and the basal part of the cells is less colored than the middle portion.

Osteosclerid. The walls are greatly thickened. Cell-cavity is small, almost disappearing where it is constricted. Intercellular spaces are small.

Nutrient. Cells variable in length, longer than broad. The sclerotic parenchyma brown, containing a great deal of pigment.

Inner integument. The osteosclerids and the underlying parenchyma are much compressed. The osteosclerids compose a single layer of cells, followed by several rows of elongated, thin-walled parenchyma. The inner integument readily separates from the outer testa, adhering to the endosperm.

Endosperm. The thick-walled cells of the aleurone layer form a continuous row around the mucilaginous reserve cells, these containing protein grains. The reserve tissue consists of thick-walled cells with large pore-canals; the internal part of the endosperm consists of thick-walled, elongated cells with a small lumen; all of the cells contain protein and fat.

Embryo. Epidermal cells smaller than the parenchyma below; exterior walls thickened, measuring 19–25 μ long by 11.2–25.2 μ wide; those below the outer epidermis are 30–60 μ long by 20–25 μ wide. The cells towards the procambial vessels are shorter. Several rows of palisade parenchyma under the epidermal cells of the inner face. Cells of the embryo contain protein and fat, but no starch. — (St. Louis, Pammel.)

GLEDITSCHIA MONOSPERMA, Walt. (*G. aquatica*, Marsh.)
Pl. XVIII. f. 2. Pl. XXXIV. f. 2, 9.

Testa smooth and shining, with endosperm, 1245 μ thick. Endosperm 960 μ across. Sclerotic nutrient layer 112 μ across. Malpighian cells 92–93 μ long. Osteosclerids 20 μ long. Malpighian cells agree essentially with those of *G. triacanthos;* cuticle and cuticularized layer prominent; pore-canals conspicuously enlarged in the light line region; remnants in these canals color the same as the cell contents do; light line does not stain. Gentian violet stains the contents readily. Osteosclerids as in the last species. The sclerotic nutrient layer and the inner testa agree with those of *G. triacanthos.* Endosperm cartilaginous; walls differentiated into primary, secondary and tertiary thickenings. Embryo with palisade cells on the inner surface or superior face; cells of the procambial region small. — (St. Louis, Kellogg.)

CAESALPINIEAE — Amherstieae.

TAMARINDUS, Tourn.

The thick-walled cells of the cotyledons of *Schotia speciosa* and *S. latifolia* were described by Schleiden and Vogel, who state that the walls color blue with iodine. In this respect they are like those of *Tamarindus*, long ago studied by Schleiden, and since by many other investigators. The thick-walled cells of the cotyledons of *Schotia latifolia* and the dissolution of the aleurone grains were studied by Godfrin in his work on the comparative anatomy of the cotyledons and albumen. The germination of *Peltogyne* and *Hymenaea Courbaril* was studied by Lubbock; that of *Tamarindus*, by De Candolle in his memoir on the *Leguminosae.*

TAMARINDUS INDICA, L.

Pl. XXXIII. f. 2.

Malpighian. Cells are 190–210 μ long. Light line occurs close under the cuticularized layer; cell-cavity is wide at the base; several pores extend into the cells much beyond the light line.

Osteosclerid. The cells are brown, not essentially different from those of the upper part of the nutrient layer.

Nutrient. This layer is divided into three parts; the walls of the outer are thick and star-shaped; middle portion with thinner walls; the parenchyma cells of the lower part are large, with comparatively thin walls. Numerous intercellular spaces in the parenchyma. Some of the cells contain pigment.

Endosperm. This consists of several rows of small cells. This portion of the seed is much compressed.

Embryo. The epidermal cells are small, and occur in two or three rows, followed by smaller cells. The remainder of the embryo, the reserve cellulose, consists of thick-walled cells with pore-canals. Cells of the caulicle are smaller and thin-walled. Cells contain small protein grains. Starch is absent.

MIMOSEAE — Adenanthereae.

PROSOPIS, L.

The seed of the mesquit is surrounded by a papery aril.

PROSOPIS JULIFLORA, DC.

Pl. XVIII. f. 3–3d.

Testa and endosperm are well developed. Testa quite uniform in thickness. Endosperm somewhat variable.

Malpighian. The cells are thick-walled; cuticularized layer strongly developed, as in *Cassia;* light line occurs above the middle; pore-canals project into the cell-wall below the cuticularized layer; cell-cavity wide at the base, but a mere line above the middle. Cells contain tannin, protein, and chromatophores.

Osteosclerid. Cells somewhat I-shaped, longer than broad, with a small intercellular space. The cells are smaller than those of the nutrient layer.

Nutrient. Cells thick-walled. Sclerotic walls usually colorless. Cells contain tannin.

Inner integument. It is much compressed, but on the addition of chloral hydrate the thin-walled parenchyma cells expand.

Nucellus. This consists of two to four rows of compressed cells with granular contents.

Endosperm. This layer is variable in thickness and well developed. Aleurone cells are thick-walled, usually isodiametric; the cells below are thick-walled, consisting of reserve cellulose.

Embryo. Epidermal cells much smaller than the underlying parenchyma, those of the inferior face elongated and more loosely arranged than those of the superior face. Two rows of palisade cells on the superior face of the cotyledons. Starch absent; aleurone grains and fat abundant.

MIMOSEAE — Eumimoseae.

DESMANTHUS, Willd. (*Acuan*, Med.)

The structure is much the same as in *Gymnocladus*. Cartilaginous endosperm is abundant; inner testa also present. Starch is absent.

DESMANTHUS BRACHYLOBUS, Benth. (*Acuan Illinoensis*, Mx.) *Pl. XVIII. f. 1–1b.*

Testa, with endosperm, 445 μ thick, endosperm 282 μ thick. Cotyledons 664 μ across.

Malpighian. The cells are 50–52 μ long. Cuticle and cuticularized layer are brownish, bearing colorless projections; the cuticularized layer easily separates from the remainder of the cell; the rather wide light line occurs a little below the middle. Cell-cavity wide at the base, gradually tapering upward. Several pores extend into the wall below the light line, from the cuticularized layer.

Osteosclerid. The cells are 12–14 μ long, I-shaped and thick-walled. Cell-cavity small. Cells contain some pigment and tannin, color reddish with potassium hydrate.

Nutrient. This layer is much compressed, consisting of a few to sixteen rows of thick-walled cells; differentiated into two parts, cells of the upper part thicker-walled than the lower, containing more pigment than the thin-walled lower parenchyma. Cells contain some protein matter.

Endosperm. Aleurone layer forms a continuous row of thick-walled cells with an abundance of protein; the mucilaginous reserve cellulose thick-walled, with small pore-canals; the internal part of the endosperm consists of narrow, elongated thick-walled cells with a small lumen. The cells contain some protein but not nearly as much as the middle mucilaginous portion.

Embryo. Epidermal cells are much smaller than those below, in some cases nearly isodiametric, others 8.4×9.8 μ varying to 9.8×15 μ long. Exterior walls thickened; cells below much longer and more loosely arranged, 35–42 μ long. All of the cells contain an abundance of fat and protein but no starch, also stellate compound crystals of oxalate of lime.

SCHRANKIA Willd. (*Morongia*, Britton.)

SCHRANKIA UNCINATA, Willd. (*M. uncinata*, Willd., Britton.)
Pl. XVIII. f. 5.

Testa and endosperm 85–100 μ thick.

Malpighian. The cells are 45–49 μ long. Strongly developed cuticle; a well developed cuticularized layer; the latter when treated with potash takes on a straw or brownish color. Cuticularized layer and the cuticle separate easily from the remainder of the cells; light line a little above the middle; the numerous pore-canals occur below the cuticularized layer and project into the walls below the light line; cell-cavity large at the base, narrowed rather abruptly. Cells contain an abundance of tannin and some protein matter.

Osteosclerid. The cells are thick-walled, 15–16 μ long. Cavity very much reduced, containing pigment and tannin.

Nutrient. Walls of the cells thickened, slightly colored; containing an abundance of pigment and tannin.

Endosperm. In the widest part 30 μ thick. The aleurone layer consists of smaller cells, the remainder, of thick-walled reserve cellulose.

Embryo. Epidermal cells smaller than the underlying parenchyma of the inferior face. Several rows of elongated palisade cells on the superior face. Cells contain fat and protein but no starch.

MIMOSEAE — Acacieae.

ACACIA, Tourn.

Anatomically the genus is closely allied to *Desmanthus* and *Cassia*. The thick-walled sclerotic cells of the nutrient layer are like those of *Cassia* and *Gymnocladus*. The endosperm is much reduced, nor is the inner integument evident.

ACACIA FILICINA, Willd. (*A. filiculoides*,* Cav., Trelease.) *Pl. XXX. f. 2-2b.*

Malpighian. Cuticle not well-developed; the cuticularized layer a narrow zone; light line in the upper third of the cell; cell-cavity wide at the base, becoming very narrow in the region of the light line.

Osteosclerid. Cells small, I-shaped, with a small cavity.

Nutrient. Layer is divided into two parts. Cells of the upper part thick-walled. Cells of the lower elongated and the walls not so thick.

Endosperm. Much reduced, consisting of a single row of cells, the aleurone layer.

Embyro. Epidermal cells of the cotyledons small, usually a little longer than broad. The parenchyma cells of the inner face much larger than those of the epidermis, with small intercellular spaces. A single row of palisade cells on the superior face of the cotyledons; these are smaller than the underlying parenchyma. Cells contain fat and protein.

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* This is an error in Britton and Brown's Illustrated Flora. Cavanilles (Ic. 1: 55. *pl. 78.* 1791) wrote *Mimosa filicioides* and is correctly quoted in Watson's Bibliographical Index. In Kew Index it is given as *Mimosa filicoides* Cav.

SYNOPSIS OF TRIBES AND GENERA.

The following synopsis is based on the characters of the testa, endosperm, and cotyledons. I have followed the arrangement given by Bentham and Hooker in their "Genera Plantarum."

PAPILIONACEAE.

Podalyrieae.

Light line close under the cuticle; osteosclerids I-shaped; nutrient layer and endosperm well developed. Embryo contains fat and protein grains; starch is absent; palisade cells present.

1. Malpighian cells covered with resiniferous bodies.................................. *Baptisia.*
1. Malpighian cells not reisiniferous.......... *Thermopsis.*

Sophoreae.

Light line close under the cuticle; osteosclerids I-shaped; nutrient layer compressed; endosperm well developed. Palisade cells present.

1. Reserve material consists of fat and aleurone grains.......................... *Cladrastis.*
1. Reserve material consists of fat, aleurone grains, and small starch grains............ *Sophora.*

Genisteae.

Light line close under the culticle; osteosclerids I-shaped; endosperm well developed or nearly absent. Palisade cells present or absent.

1. Endosperm nearly absent.................. *Lupinus.*
1. Endosperm more developed (2).
2. Endosperm not copious.................. *Crotalaria.*
2. Endosperm copious (3).
3. Nutrient layer much compressed........... *Laburnum.*
3. Nutrient layer less compressed.............. *Genista.*

Trifolieae.

Cuticularized layer of the Malpighian cells well developed; osteosclerids rhomboidal, with longitudinal pore-canals; endosperm gelatinous, rather copious; reserve material consists of aleurone grains, fat and small starch grains. Cotyledons with palisade cells.

1. Cone-like projections of the cuticularized layer absent.......................... *Trifolium.*
2. Cone-like projections present..*Medicago* and *Melilotus.*

Loteae.

Cuticularized layer well developed; osteosclerids I-shaped; endosperm evident, gelatinous. Cotyledons with palisade cells; starch absent.............................*Hosackia.*

Galegeae.

Cuticularized layer of the Malpighian cells usually not prominent; osteosclerids I-shaped; endosperm various, usually evident; reserve material usually consists of aleurone grains and fat, exceptionally starch.

PSORALIEAE. Cuticularized layer and mycotic cells variable. Cotyledons with palisade cells.

1. Mycotic layer evident.........................*Psoralea.*
1. Mycotic layer not evident (2).
2. Cuticularized layer not greatly developed. Starch grains present or absent..*Dalea*, *Petalostemon* and *Amorpha.*

INDIGOFEREAE. Malpighian cells long; osteosclerids I-shaped; endosperm conspicuous. Cotyledons with palisade cells; starch absent.............................*Indigofera.*

TEPHROSIEAE. Cuticularized layer not strongly marked; osteosclerids I-shaped; mycotic layer variable; endosperm reduced. Palisade parenchyma present or absent.

1. Lysigenetic canals in cotyledons............*Tephrosia.*
1. Lysigenetic canals absent; an abundance of starch..............................*Wistaria.*

ROBINIEAE. Cuticularized layer strongly developed; osteosclerids I-shaped; endosperm well developed; starch absent..*Robinia.*

ASTRAGALEAE. Cuticularized layer narrow, osteosclerids I-shaped; endosperm well developed. Cotyledons with palisade cells.

1. Osteosclerids usually with longitudinal pores...............................*Astragalus.*
1. Osteosclerids without longitudinal pores (2).
2. Nutrient layer much compressed..........*Glycyrrhiza.*
2. Nutrient layer less compressed............*Oxytropis.*

Hedysareae.

Malpighian cells usually well developed; osteosclerids I-shaped; endosperm variable, copious or reduced. Cotyledons usually with several rows of palisade cells. Reserve material consists of fat, aleurone grains and exceptionally starch as well.

CORONILLEAE. Light line removed some distance from the cuticle; osteosclerids I-shaped; nutrient layer compressed;

endosperm mucilaginous. Cotyledons with one or more rows of palisade cells; chlorophyll grains in the cotyledons. *Coronilla.*

EUHEDYSAREAE. Cuticle irregular, cuticularized layer sharply defined; endosperm reduced. Starch present. *Hedysarum.*

AESCHYNOMENEAE. Cuticularized layer narrow; osteosclerids I-shaped; nutrient layer much compressed; endosperm present, more or less evident.......... *Aeschynomene.*

ADESMIEAE. Malpighian cells absent, short, or well developed; osteosclerids well developed or scarcely differentiated from the nutrient layer; endosperm reduced. Palisade parenchyma of the cotyledons wanting or well developed. Reserve material consists of fat, starch, and aleurone grains.

1. Malpighian cells wanting.............. *Chapmannia.*
1. Malpighian cells present (2).
2. Malpighian cells short and thin-walled (3).
2. Malpighian cells long and thick-walled........ *Zornia.*
3. Cotyledons contain starch.................. *Arachis.*
3. Cotyledons do not contain starch......... *Stylosanthes.*

DESMODIEAE. Cuticularized layer inconspicuous, light line close under the cuticle; osteosclerids I-shaped; endosperm present, the amount variable. Cotyledons with several rows of palisade cells; starch absent.

1. Endosperm usually copious................ *Lespedeza.*
2. Endosperm less copious.................. *Desmodium.*

Vicieae.

Malpighian cells well developed, surface usually irregular, cells contain one or more chromatophores; osteosclerids I-shaped, large with longitudinal pore-canals; nucellus more or less evident; endosperm reduced. Epidermal cells of the cotyledons much smaller than those of the parenchyma, palisade cells absent. Reserve food material consists of fat, starch, and aleurone grains. It is difficult to differentiate *Vicia* and *Lathyrus.*

1. Cuticle slightly irregular on the surface........ *Pisum.*
1. Cuticle very irregular on the surface (2).
2. Lateral walls of Malpighian cells undulated...... *Cicer.*
2. Lateral walls not undulated....... *Vicia* and *Lathyrus.*

Phaseoleae.

Cuticularized layer inconspicuous, Malpighian cells usually long; osteosclerids usually I-shaped; mycotic layer evident, or reduced; endosperm nearly wanting. Epidermal cells much smaller than the underlying cells, palisade cells usually wanting. Reserve food consists of fat, protein, and starch or reserve cellulose.

GLYCINEAE. Osteosclerids I-shaped; endosperm reduced, palisade cells usually wanting. Reserve food consists of fat, aleurone grains and reserve cellulose.

1. Palisade cells present in cotyledons .... *Glycine.*
1. Palisade cells absent (2).
2. Cell-walls of cotyledons very thick........ *Centrosema.*
2. Cell-walls of cotyledons less thickened (3).
3. Cell-walls of cotyledons more or less stratified, with large pore-canals................ *Clitoria.*
3. Cell-walls of cotyledons with small pore-canals............................ *Amphicarpaea.*

GALACTIEAE. Cuticle somewhat uneven, cuticularized layer present; Malpighian cells with cell-cavity large at the base; osteosclerids I-shaped; mycotic layer evident. Endosperm consists of the aleurone layer and several rows of small cells. Epidermal cells much smaller than those of the parenchyma. Reserve material consists of fat, starch, and aleurone grains. *Galactia.*

ERYTHRINEAE. Malpighian cells long; osteosclerids I-shaped; endosperm nearly wanting. Epidermal cells much smaller than those of the parenchyma, palisade cells present or wanting. Reserve food consists of starch, aleurone grains, and fat.

1. Starch grains large......................... *Mucuna.*
1. Starch grains small......................... *Apios.*

EUPHASEOLEAE. Malpighian cells usually long; osteosclerids usually I-shaped; nutrient layer well-developed; mycotic layer conspicuous or nearly wanting; endosperm nearly wanting. Epidermal cells of the cotyledons much smaller than those of the parenchyma. Reserve food material consists of starch, aleurone grains and fat.

1. Mycotic layer of testa conspicuous.......... *Phaseolus.*
1. Mycotic layer not conspicuous (2).
2. Surface of Malpighian cells covered with more or less deciduous hairs.......... *Strophostyles.*
2. Surface of Malpighian cells not covered with hairs (3).
3. Spongy parenchyma of hilar region greatly developed.............................. *Dolichos.*
3. Spongy parenchyma of hilar region less developed .... *Vigna.*

CAJANEAE. Malpighian cells long; osteosclerids I-shaped; endosperm nearly wanting. Epidermal cells of the cotyledons much smaller than those of the parenchyma. Reserve material consists of starch, protein, and fat.......... *Rhynchosia.*

CAESALPINIEAE.

Bauhinieae.

Cuticularized layer well developed, Malpighian cells long; osteosclerids not essentially different from the parenchyma of the nutrient layer; endosperm copious, cartilaginous. Several rows of palisade cells in the cotyledons. Reserve food material consists of fat and aleurone grains.......... *Cercis.*

Eucaesalpinieae.

Cuticularized layer conspicuous, Malpighian cells usually very long; osteosclerids usually not essentially different from the cells of the nutrient layer except that they are strongly sclerotic; inner testa evident as a rule; endosperm copious, cartilaginous. Usually several rows of palisade cells. Reserve food material consists of fat and aleurone grains.

1. Palisade cells absent.................. *Gymnocladus.*
1. Palisade cells present (2).
2. Malpighian cells very long................ *Gleditschia.*
2. Malpighian cells relatively short........ *Hoffmanseggia.*

Cassieae.

Cuticularized layer evident, Malpighian cells variable as to length in different species; osteosclerids I-shaped or like the underlying sclerotic cells of the nutrient layer; inner testa much compressed; endosperm copious, cartilaginous. Cotyledons with palisade cells. Reserve food material consists of fat and aleurone grains........................ *Cassia.*

MIMOSEAE.

Amherstieae.

Cuticularized layer not evident, Malpighian cells long and thick-walled; osteosclerids not essentially different from the cells of the well developed nutrient layer; endosperm nearly wanting. Parenchyma cells of the cotyledons thick-walled. Reserve material consists of fat, aleurone grains and reserve cellulose................................ *Tamarindus.*

Adenanthereae.

Cuticularized layer evident, Malpighian cells thick-walled, light line above the middle of the cell; osteosclerids I-shaped, small and compressed; nutrient layer of thick-walled sclerotic cells; inner integument much compressed; endosperm co pious and cartilaginous. Epidermal cells much smaller than those of the parenchyma, two rows of palisade cells. Reserve material consists of fat and aleurone grains........*Prosopis.*

Eumimoseae.

Cuticularized layer well marked, Malpighian cells thick-walled; osteosclerids I-shaped, reduced, and essentially like the sclerotic cells of the nutrient layer; epidermal cells of the cotyledons smaller than those of the parenchyma, palisade cells in several rows. Reserve material consists of fat and aleurone grains.

1. Osteosclerids I-shaped..................*Desmanthus.*
1. Osteosclerids not I-shaped................*Schrankia.*

Acacieae.

Cuticularized layer a narrow zone, Malpighian cells thick-walled, not greatly elongated; osteosclerids I-shaped; endosperm much reduced. Epidermal cells of the cotyledons smaller than those of the parenchyma, one row of palisade cells...*Acacia.*

SUMMARY.

Under the general head of macrosclerids I have discussed quite fully the Malpighian cells, with reference to the light line, which I believe to be chemically and physically modified. The light line occurs in widely separated orders. The Malpighian cell separates at the light line, that being a point of least resistance. The Malpighian cells are either lignified or consist of cellulose. In some cases the cells are only partially lignified. They are lignified in some *Leguminosae*, also in some other orders. These cells always contain tannin and usually some pigment. The cuticularized layer is well developed in *Medicago* and *Gymnocladus.* The function of the Malphighian cells is largely one of protection.

The osteosclerids vary in different tribes, as shown in the synopsis; they usually carry pigment and tannin. The walls are not infrequently provided with longitudinal pore-canals. The nutrient layer in the immature seed is well developed. When the seed reaches maturity this layer becomes much compressed, its function, that of supplying nourishment to the developing seed, ceases when the ripening process begins.

The mycotic layer is much compressed and may be looked upon as a nutrient layer in the developing seed. The cells of this layer are narrow and hypha-like in their appearance.

The inner integument is suppressed except in *Caesalpinieae.* It is evident here when the section is treated with chloral hydrate.

The nucellus is much compressed. In some genera, notably *Gymnocladus*, *Pisum* and *Lathyrus*, it is more evident.

The endosperm varies greatly; in the *Caesalpinieae* it is well developed, conspicuous also in some of the so-called exalbuminous seeds, like *Trifolium* and *Medicago.* The aleurone layer is universally present, though frequently not conspicuous. The endosperm is mucilaginous and consists of reserve cellulose.

The structure of the embryo varies greatly. The epidermal cells are smaller than those of the underlying parenchyma. The parenchyma may be more loosely arranged, as in *Vicieae* and many of the *Phaseoleae,* or there are well defined palisade layers present on the upper side of the cotyledons. It is possible to foretell the method of germination except in *Phaseoleae.* Some of these germinate hypogaeously. In all other cases, so far as I know, the presence of palisade cells corresponds to epigaeous germination. In the *Vicieae* studied, palisade cells are wanting; these germinate hypogaeously.

The reserve food consists of cellulose, starch, fat, and protein, but in the majority of species it consists of fat and protein only. Lysigenetic canals occur in *Tephrosia.* Procambial vessels present, usually without spiral ducts. Spiral ducts occur in *Gymnocladus*, *Vicia Faba*, and *Phaseolus multiflorus.*

In the systematic portion of the work, representatives of three suborders were studied, namely *Papilionaceae*, *Caesalpinieae*, and *Mimoseae.* From this study it is evident that these cannot be treated as three separate orders. The order *Krameriaceae*, which by some recent writers is placed between the *Caesalpinieae* and *Papilionaceae*, has little in common with the *Leguminosae.* Most of the *Adesmieae* are strikingly different from the other tribes of *Leguminosae.* Of the 23 tribes given by Bentham and Hooker, 16 were studied, embracing 59 genera and 103 species, fairly representative of the order.

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EXPLANATION OF ILLUSTRATIONS.

PLATES VII–XXXV.

The lettering is the same throughout unless otherwise stated. M = Malpighian cells. ll = light line. l = lumen. o = osteosclerid. n = nutrient layer. n′ = remnants of the nucellus. a = aleurone layer. ale = aleurone grains. en = endosperm. en′ = internal part of endosperm. em = embryo. s = starch grains. cot. = cotyledons. sp = spiral ducts. a′ = epidermal cells of cotyledons. cr = crystals. hy = hilar groove above tracheid island.

Plate VII. — I, *Baptisia leucantha:* light line close to the cuticle; osteosclerids large; remnants of the nucellus present; epidermal cells of embryo smaller than those of parenchyma; fat globules and protein grains in cells.— II, *Thermopsis caroliniana:* nutrient layer and nucellus as in *Baptisia;* endosperm differentiated into three parts.— IIb, lower part of endosperm.— IIc, embryo, epidermal cells, and parenchyma.

Plate VIII. — I, *Melilotus officinalis:* prominent conical points above the light-line. — Ib, palisade cells of the embryo, upper face. — Ic, a single cell of the endosperm with thick walls; small starch grains in embryo. — II, *Melilotus alba:* small starch grains in the embryo; thick-walled endosperm cell shown below the embryo. — III, *Medicago lupulina:* — IIIb, somewhat rhomboidal osteosclerids more magnified. — IV, *Medicago denticulata:* secondary and tertiary walls dissolved; small starch grains in the embryo. — IVb, single I-shaped osteosclerid. — V, *Melilotus officinalis:* general longitudinal view of the seed; osteosclerids, spongy parenchyma of the nutrient layer, endosperm, and two cotyledons.

Plate IX. — I, *Lupinus pusillus:* cuticle and cuticularized layer above the light-line; several chromatophores in Malpighian cells; spiral duct in the nutrient layer; nucellus present; endosperm reduced. — II, *Trifolium agrarium:* — IIb, cells of embryo. — III, *Lupinus albus.* — IV, *Lupinus* sp. figure traced from Malpighius, Anatom. Plant. — V, *Trifolium reflexum:* endosperm of thick-walled cells; small starch grains in embryo. — VI, *Trifolium pratense:* chromatophores in cell-cavity; thick-walled endosperm cells. — VIb, embryo.

Plate X. — I, *Sophora sericea.* — Ib, cells of embryo with small starch grains. — Ic, lower part of the endosperm. — II, *Genista tinctoria:* thick-walled endosperm cells. — IIb, cells of embryo. — IIc, aleurone grains in cells. — III, *Cytisus scoparius:* thicked-walled endosperm cells and a compressed layer next to the embryo. — IV, *Crotalaria sagittalis:* nutrient layer divided into two parts. — V, *Cladrastis tinctoria:* conspicuous cuticularized layer above the light line; thick-walled reserve-cellulose of the endosperm with pore-canals.

Plate XI. — I, *Psoralea floribunda:* osteosclerids much compressed. — Ib, a more enlarged view of the osteosclerids; mycotic layer well developed, brown; remnants of the nucellus at *n′*. — II, *P. cuspidata:* compressed nutrient layer below the osteosclerids; mycotic layer well developed, brown. — IIb, cells of the cotyledons with aleurone grains *o′;* intercellular space at *i.* — III, *Amorpha canescens:* cell-walls of the endosperm thick; the epidermal cells of the embryo smaller than those of the parenchyma below. — IIIb, palisade cells of the embryo, superior face. — IV, *P. melilotoides:* cell-walls of the osteosclerids thick; mycotic layer much reduced. — IVc, cells of the embryo with protein, fat, and small starch grains. — V, *Hosackia Purshiana:* reserve cellulose of endosperm with thick-walled cells. — Vb, embryo with palisade cells of the superior face of the cotyledon. — VI, *Amorpha fruticosa:* chromatophores in the Malpighian cell; the osteosclerids followed by the nutrient layer. — VIb, walls of the aleurone layer greatly thickened; cells of the lower part of the endosperm with thin walls.

Plate XII. — I, *Dalea alopecuroides:* — Ib, spiral ducts in the nutrient layer. — IIa. *Tephrosia hispidula:* gelatinous endosperm; small epidermal cells of embryo. — IIb, simple crystals *cr* in cotyledons below the epidermal cells. — III, *Petalostemon violaceus.* — IV, *Tephrosia virginiana:* reserve cellulose of endosperm; epidermal cells of the embryo smaller than the underlying cells. — IVc, lysigenetic canal with its surrounding cells. — V, *Dalea alopecuroides:* sections from different parts of seed. — VI, *Petalostemon candidus:* thick-walled cells of the endosperm below the nutrient layer. — VIb, embryo with protein grains and fat. — VII, *Dalea laxiflora:* thick-walled reserve cellulose of endosperm.

Plate XIII. — I, *Indigofera leptosepala:* endosperm differentiated into three parts. — Ia, embryo. — II, *Oxytropis deflexa:* cells of nutrient layer thick-walled. — III, *Astragalus mexicanus:* separated Malpighian cells with well-developed cuticularized layer and cuticle. — IIIb, surface view of the Malpighian cells. — IV, *Oxytropis Lamberti:* cells of aleurone layer thick-walled. — V, *Astragalus canadensis:* cells of aleurone layer large, followed by the gelatinous endosperm. — Vb, cell-cavity with chromatophore after the action of sulphuric acid.

Plate XIV. — I, *Robinia Pseudacacia:* — Ia, general view of cross-section of the seed showing different layers in position. — Ib, portion of upper part of Malpighian cell greatly magnified to show cuticularized layer *c* with pore-canals projecting into cell. — Ic, Malpighian cell showing light line in upper part. — Id, young Malpighian cell greatly magnified. — Ie, osteosclerids greatly magnified, showing longitudinal pore-canals. — If, cells of endosperm with thick-walled reserve cellulose. — II, *Wistaria frutescens:* general view, broad cuticularized layer above the light line; chromatophores in upper part of cells. — IIb, section through outer part of embryo; starch grains in the cells; the interior large, and showing intercellular spaces. — IIc, lower part of nutrient layer and mycotic layer. — IId, an oblique view of the Malpighian cells.

Plate XV. — I, *Desmodium canescens:* cells of embryo without starch; nutrient layer differentiated into two parts. — II, *Desmodium strictum:* three rows of cells of the nutrient layer, followed by the aleurone, and reserve cellulose of the endosperm. — IIIa, *Desmodium canescens:* superior face of cotyledons; small epidermal cells and palisade parenchyma below; cells contain fat and aleurone grains. — IIIb, *Lespedeza Stuvei:* embryo cells of lower face. — IIIc, endosperm. — IV, *Aeschynomene hispida:* nutrient layer differentiated into two parts; cells of the aleurone layer smaller than those of the reserve cellulose of the endosperm. — V, *Lespedeza virginica:* large chromatophore in the upper part of Malpighian cell; cells of aleurone layer smaller than those of the reserve cellulose. — VI, *Glycyrrhiza lepidota:* nutrient layer well developed; aleurone cells large; thick-walled cells of reserve cellulose below. — VII, *Hedysarum boreale:* well developed cuticularized layer above the light line; large chromatophore in the Malpighian cell; epidermal cells of the embryo large.

Plate XVI. — I, *Vicia sativa:* minute pore-canals below the cuticularized layer; upper part of the Malpighian cell light colored with a large chromatophore; osteosclerids with longitudinal pore-canals. — II, *Vicia sativa:* Malpighian cells irregular on surface; cross-section of spiral ducts in the nutrient layer; epidermal cells of the embryo without starch. — IIb, starch grains which have undergone disintegration. — III, *Lathyrus maritimus:*

irregular outline of cell-cavity and small pore-canals. — IV, *Lespedeza capitata.* — V, *L. Stuvei.* — Vb, *L. virginica:* thick-walled reserve cellulose of the endosperm. — Vc, *L. Stuvei:* aleurone layer and remainder of endosperm. — VI, *Vicia Faba:* Malpighian cells with lateral pore-canals. — VIb, *Lathyrus venosus:* thick-walled aleurone cells; starch grains stratified. — VIc, endosperm cells.

Plate XVII. — I, *Cercis canadensis:* osteosclerids not I-shaped; cells of nutrient layer very irregular; crystals in epidermal cells of the embryo. — Ib, lower part of the endosperm. — II, *Galactia pilosa:* showing compressed nutrient layer, and the mycotic layer below; large starch grains in embryo. — III, *Amphicarpaea monoica:* osteosclerids elongated, I-shaped; aleurone grains in cells of embryo. — IV, *Rhynchosia latifolia:* endosperm reduced, and epidermal cells smaller than those of the starch layer below; starch grains large and stratified. — V, *Chapmannia floridana:* testa delicate; *e* epidermal cells, light line absent; spiral ducts in nutrient layer.

Plate XVIII. — I, *Desmanthus brachylobus:* sclerotic cells of nutrient layer thick-walled; cells of the reserve cellulose in lower part of cells smaller; some of the cells of the embryo contain crystals of calcic oxalate. — Ib, cuticularized layer below cuticle. — II, *Gleditschia monosperma:* Malpighian cells with cuticle and cuticularized layer somewhat reduced; pore-canals extend to the light line; cells of the inner integument expanded after the addition of chloral hydrate; aleurone cells smaller than those of the reserve cellulose. — III, *Prosopis juliflora:* conspicuous cuticularized layer. — IIIb, expanded thin-walled parenchyma cells of the inner integument followed by the thick-walled cells of the nucellus and endosperm. — IIIc, superior face of the two cotyledons, showing palisade cells. — IIId, inferior face of cotyledons; walls of the epidermal cells thickened. — IV, *Clitoria serrulata.* — V, *Schrankia uncinata.*

Plate XIX. — I, *Gleditschia triacanthos:* the wide cuticularized layer below the cuticle; to the right a single Malpighian cell. — Ib, stratified reserve cellulose of endosperm. — II, *Hoffmanseggia Jamesii:* the nucellus reduced; endosperm divided into two parts. — IIb, embryo. — III, *Centrosema virginianum:* nutrient layer differentiated into two parts, nucellus reduced. — IV, *Apios tuberosa:* endosperm and nucellus reduced; the epidermal cells of embryo smaller than the underlying starch cells; the latter contain small starch grains. — V, *Centrosema virginianum:* thick-walled reserve cellulose of the cotyledons.

Plate XX. — I, *Clitoria Mariana.* — II, *Cassia nictitans:* thick-walled sclerotic cells of nutrient layer, followed by the compressed layer of the inner integument. — III, *Vigna glabra:* nutrient layer compressed; mycotic layer reduced; the endosperm consists of a single row of cells; the epidermal cells much smaller than those of the starch layer below. — IV, *Cassia Chamaecrista:* with two light lines; inner integument compressed or merging into the cells of nutrient layer. — IVb, IVc, isolated Malpighian cells. — IVd, embryo. — IVe, portion of the Malpighian layer; cells separating at the light line. — V, *Cassia marylandica.* — Vb, osteosclerids.

Plate XXI. — I, *Phaseolus lunatus:* osteosclerids with lateral projections. — Ib, single Malpighian cell, enlarged. — Ic, osteosclerid. — Id, cells of the embryo. — II, *Phaseolus multiflorus:* spiral ducts in nutrient layer. — IIb, Malpighian cells. — IIc, tangential view of osteosclerids. — IId, pore-canals in cell-walls of mycotic layer. — IIe, starch grains. — IIf, striae of osteosclerids. — IIg, group of cells of the mycotic layer. — III, *Strophostyles pauciflorus.* — IV, *Strophostyles angulosa:* epidermal cells *e'* above the Malpighian cells. — V, *Phaseolus perennis.*

Plate XXII. — I, *Stylosanthes elatior:* short Malpighian cells; endosperm of a single row of cells. — Ib, palisade parenchyma with crystals in cells. — Ic, surface view of Malpighian cells. — II, *Coronilla montana.* — III, *Arachis hypogaea:* Malpighian cells with a large cell-cavity; nucellus compressed. — IIIb, surface view of Malpighian cells. — IIIc, cells of embryo in region of caulicle. — IIId, a single cell of the embryo showing aleurone grain with a crystalloid and globoid. — IIIe, showing starch grains, and procambial vessels at *prc.* — IIIf, embryo from the inferior face. — IIIg, superior face of cotyledon.

Plate XXIII. — I, *Lathyrus sativus:* Malpighian cells irregular on the surface. — Ib, section through the caulicle. — Ic, single starch grain more magnified. — II, *Desmodium nudiflorum:* the arillate processes shown at *ar,* also the hilum and hilar groove; the spongy parenchyma below the funiculus; endosperm the darker shaded portion at the upper end of the cotyledons, and the spongy parenchyma below the Malpighian layer. — III, *Coronilla montana:* showing position of the procambial vessels as well as the palisade parenchyma, two cells with chlorophyll grains. — IV, *Mucuna pruriens:* longitudinal section in region of radicle; arillate process at *ar;* the large micropyle leading to the radicle, showing the root-cap *rc;* the vegetative point *vp,* the plerome *pl* and the periblem and dermatogen *d.*

Plate XXIV. — I, *Medicago sativa:* — Ib, surface view of endosperm cells. — Ic, more magnified view of Malpighian cell showing cuticle, cuticularized layer, and the narrow cell-cavity *l.* — Id, osteosclerids, somewhat magnified. — Ie, endosperm treated with dilute hydrochloric acid. — If, section through inferior face of cotyledon, showing small starch grains. — Ig, superior face of cotyledon with palisade cells. — Ih, section through procambial vessel. — II, *Medicago lupulina:* endosperm mounted in water, showing the dissolution of the cell-walls. — IIb, cross-section through a procambial bundle.

Plate XXV. — I, *Gymnocladus canadensis:* cuticle shown at *c;* the cuticularized layer at *cl.* — Ib, the inner integument shown at *ii* with osteosclerid-like cells in lower portion and remnants of the nucellus. — Ic, endosperm with partial dissolution of cell-walls. — Id, the two cotyledons in position. — Ie, lower portion of the endosperm. — If, spiral duct of the procambial bundle. — Ig, inferior face of the cotyledon.

Plate XXVI. — I, *Vicia americana:* large chromatophore in Malpighian cell. — Ib, starch grains more magnified. — Ic, surface view of osteosclerids from hilar region. — II, *Vicia Faba.* — IIa, two rows of Malpighian cells in hilar region. — IIb, two starch cells, showing surface view of pore-canals in upper, and starch in lower cell. — IIc, cells of nutrient layer, one cell densely filled with pigment; cell below with remnants of protoplasm. — IId, spiral duct in cotyledon. — IIe, double Malpighian layer and tracheid island *tr.* — IIf, osteosclerids from the hilar region — IIg, surface view of osteosclerids. — IIh, endosperm. — IIj, upper figure, inferior face of cotyledons; the epidermal cells contain leucoplastids: lower figure, superior face of cotyledon.

Plate XXVII. — 1, *Mucuna pruriens:* section through hilum with the two arillate processes *ar* made up of elongated sclerotic cells; the hilar groove *hg;* spongy parenchyma surrounding the tracheid island except the two rows of thin-walled cells which form a sheath about the island. — Ib, an oblique section, showing a general view of the micropyle, radicle, tracheid island, and arillate processes. — Ic, shows a portion of the funiculus, the arillate processes, hilum, and collapsed parenchyma. — Id, asparagin crystals in cells of cotyledons. — II, *Phaseolus vulgaris:* crystals in osteosclerid layer; epidermal cells of the embryo contain no starch.

Plate XXVIII. — I, *Lathyrus odoratus:* Malpighian cells irregular on the surface; nucellus compressed. — Ib, portion of an isolated Malpighian cell in hilar region. — II, *Lathyrus latifolius.* — III, *Lathyrus sylvestris.* — IV, *Petalostemon candidus:* cotyledons, superior face with palisade cells. — IVb, inferior face of cotyledons. — IVc, endosperm. — V, *Lathyrus sylvestris:* spongy parenchyma of hilar region, showing peculiar cellulose thickenings of walls.

Plate XXIX. — I, *Tephrosia virginiana:* cross-section of cotyledon showing position of the lysigenetic canals. — Ib, the lysigenetic canal after treatment with chlor-iodide of zinc. — Ic, cross-section through cotyledon, superior face, after treatment with sulphuric acid and iodine.— Ie, different view of reservoir. — If, Ig, *Tephrosia leucantha:* lysigenetic canal. — II, *Cicer arietinum.* — IIb, embryo with starch grains. — IIc, Malpighian cells more magnified.

Plate XXX. — I, *Pisum sativum:* nutrient layer divided into two parts, epidermal cells of cotyledons much smaller than the starch cells. — II, *Acacia filicina:* cells of nutrient layer thick-walled; nucellus compressed. — IIb, two adjacent cotyledons of superior face showing palisade cells. — III, *Desmodium Dillenii:* inferior face of cotyledon; small epidermal cells and parenchyma below. — IIIb, two rows of palisade cells, upper face of the cotyledon; aleurone grains in cells.

Plate XXXI. — I, *Sterculia heterophylla:* Malpighian cells with two light lines; below the light lines a darker zone; above the Malpighian cells outer dark-brown cells of testa. — II, *Marsilia quadrifolia:* cross-section through the wall of sporangium; light line in middle of cell. — III, *Zizyphus vulgaris:* surface view of Malpighian cells shown at *ms;* minute canals from peripheral walls. — IV, *Sicyos angulata:* light line near the cuticle; cell-cavity with branched canals. — V, *Ipomoea tuba:* light line in upper part; cell-cavity very small; a row of small cells above the Malpighian layer, which act as a support for the hairs of the seed; an entire cell shown to the right. — VI, *Dracocephalum parviflorum:* epidermal cells; the Malpighian layer below with two light lines; several chromatophores in the cell-cavity; the cells of the nutrient layer are abundantly supplied with tannin.

Plate XXXII. — I, *Canna indica:* Malpighian cells with light line in middle. — II, *Geranium carolinianum:* small epidermal cells above the Malpighian layer; these cells with crystals. — III, *Gossypium herbaceum:* walls of Malpighian cells greatly thickened in lower part; cell-cavity only occurs in the upper one-third of the cell; two light lines. — IV, *Tilia pubescens:* light line in upper part of Malpighian cell. — V, *Malvastrum angustatum:* the epidermal cells, the supporting layer and Malpighian layer. — VI, *Nelumbo lutea:* Malpighian cell. — VII, *Adolphia californica:* light line in upper part of Malpighian cell. — VIII, *Ceanothus americanus:* the Malpighian cells followed by the nutrient layer. — VIIIb, surface view of

Malpighian cells. — IX, *Glycine hispida.* — IXb, embryo; fat globules *f*, and protein.

Plate XXXIII. — I, *Vigna Catjang:* Ib, embryo. — Ic, surface view of osteosclerids. — II, *Tamarindus indica:* parts of nutrient layer and embryo shown; cells of the embryo thick-walled. — III, *Lens esculenta:* surface view of Malpighian cells; somewhat irregular on surface. — IIIb, a few cells of the embryo. — IV, *Dolichos Lablab.* — V, *Glycine hispida: a'*, epidermal cells; aleurone grains in parenchyma cell; *el* lower surface, *eu* upper surface with palisade cells.

Plate XXXIV. — I, *Lathyrus venosus:* Malpighian cell immediately after the addition of chlor-iodide of zinc; light line, cuticularized layer and the walls of osteosclerids take on a blue color; starch grains blackish. — II, *Gleditschia monosperma:* thick-walled reserve cellulose cells of endosperm treated with chlor-iodide of zinc color blue; the contents, yellowish. — III, *Vigna Catjang:* Malpighian cell treated with sulphuric acid and iodine. — IV, *Desmodium canadense:* treated with sulphuric acid and iodine. — V, *Cassia nictitans:* treated with ferric chloride. — VI, *Nelumbo lutea:* chlor-iodide of zinc colors the walls blue; phloroglucin and hydrochloric acid give no reaction, the cell retains its normal color. — VII, *Rhynchosia phaseoloides:* Malpighian and osteosclerid cells treated with ferric chloride, give the reaction for tannin; light line remains unchanged. — VIII, *Canna indica* treated with phloroglucin and hydrochloric acid, no reaction. — IX, *Gleditschia monosperma:* Malpighian cells treated with chlor-iodide of zinc, walls colored blue, the wide light band in upper part of cell, straw-colored. — X, *Tropaeolum majus:* thick-walled cells from cotyledon treated with iodine color blue, the reaction for amyloid. — XI, *Geranium carolinianum:* treated with phloroglucin and hydrochloric acid; Malpighian cells retain their normal color; the cells below slightly lignified. — XII, *Marsilia quadrifolia:* no reaction on the addition of phloroglucin and hydrochloric acid; walls color blue with chlor-iodide of zinc.

Plate XXXV. — I, *Dracocephalum parviflorum:* Malpighian cell treated with phloroglucin and hydrochloric acid, walls strongly lignified, — II, *Sterculia heterophylla:* lower portion of wall strongly lignified. — III, *Lathyrus venosus:* Malpighian cells natural color; starch grains after the addition of iodine. — IV, *Ceanothus americanus:* Malpighian cells treated with phloroglucin and hydrochloric acid; walls strongly lignified. — V, *Gossypium herbaceum:* lower part of cells strongly lignified. — VI, *Sicyos angulatus:* Malpighian cells strongly lignified, except the light line and upper part of cell. — VII, *Ipomoea tuba:* treated with chlor-iodide of zinc. — VIII, *Ipomoea tuba:* treated with phloroglucin and hydrochloric acid; cells very slightly lignified; walls below the Malpighian layer lignified. — IX, *Vigna Catjang:* tracheid island and Malpighian cells lignified. — X, *Vigna Catjang:* single Malpighian cell from lateral part of seed, lignified. — XI, *Tilia pubescens:* lower part of cell strongly lignified; light line remains unchanged when treated with phloroglucin and hydrochloric acid. — XII, *Baptisia leucantha:* Malpighian cells slightly lignified, the osteosclerids less so.

Issued June 29, 1899.

TABLE A.—REACTIONS OF MALPIGHIAN CELLS, EXCEPT LIGHT LINE AND CUTICULARIZED LAYER.

NAME OF SPECIES.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	PHLOROGLUCIN & HYDROCHLORIC ACID.	CHLORAL HYDRATE.	FUCHSINE.	HAEMATOXYLIN. DELAFIELD.	FERRIC CHLORIDE.	IODINE.	NORMAL COLOR. CHEMICAL COMPOSITION, AND REACTIONS.
Gleditschia triacanthos.	Cell-walls color blue, deeper than osteosclerids.	Cell-walls color light blue, disintegrated. Walls separate at light line.	No reaction.	Swells and becomes clear.	Cell-walls color deeply.	Contents color deeply.	Colors bluish, deeper at base.	Content color brown. Walls light straw color.	Nearly colorless. Contains tannin. Walls consist of cellulose.
Astragalus canadensis.	Cell-walls color blue, deeper than osteosclerids. Chromatophores brown	Cell-walls color blue, rapidly disintegrated. Walls separate readily at light line.	No reaction.	Swells and becomes clear.	Colors readily.	Chromatophores stain deeply.	Colors bluish, becoming black.	Chromatophores color brown.	Yellowish, nearly colorless. Contain tannin. Cell-walls consist of cellulose.
Baptisia leucophaea.	Walls only partially colored blue, less conspicuous than osteosclerids.	Walls color blue, less rapidly than osteosclerids. Rapid disintegration.	Colors a light shade of red.	Swells and walls become very clear.	Colors readily.	Chromatophores stain deeply.	Colors bluish, becoming black.	Chromatophores color brown.	Nearly colorless. Contain some tannin. Cell-walls partially lignified, also consists of some cellulose in parts.
Medicago sativa.	Walls color blue, chromatophores brown.	Cell-walls color blue rapidly. Rapid disintegration.	No reaction.	Swells and becomes very clear.	Upper part of cell-walls colors rapidly.	Contents color deeply.	Colors bluish-black.	Chromatophores color brown.	Brownish-yellow, or nearly colorless. Tannin present. Walls consist of cellulose.
Vicia Faba.	Walls color blue rapidly, chromatophores brown	Cell-walls color blue. Rapid disintegration.	No reaction.	Swells and becomes clear.	Lower part deeply colored. Upper less deep.	Contents color deeply.	Colors bluish-black.	Chromatophores color brown.	Yellowish or in thin sections nearly colorless. Contains tannin. Walls consist of cellulose.
Vigna Catjang.	Walls but slightly colored.		Colors a light shade of red.	Swells and becomes clear.					Cell-wall partially lignified, some cellulose.

TABLE B.—REACTIONS OF CUTICLE, CUTICULARIZED LAYER, AND LIGHT LINE.

NAME OF SPECIES.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	PHLOROGLUCIN & HYDROCHLORIC ACID.	CHLORAL HYDRATE.	FUCHSINE.	HAEMATOXYLIN.	FERRIC CHLORIDE.	IODINE.	CHEMICAL COMPOSITION.
Gleditschia triacanthos.	Cuticle unchanged. Cuticularized layer blue. Light lines blue but less rapidly than cell-wall.	Cuticle unchanged. Cuticularized layer blue. Light lines blue. Rapid disintegration except cuticle.	No reaction.	Cuticle does not swell.	No reaction except light lines faintly colored.	No reaction.	No reaction.	Cuticularized layer brown.	Cuticularized layer made up of cellulose. Light line, cellulose in part.
Astragalus canadensis.	Cuticle unchanged. Cuticularized layer blue. Light lines color blue slowly.	Cuticle unchanged. Cuticularized layer blue. Light line colors blue. Disintegration except cuticle.	No reaction.	Cuticle does not swell.	No reaction except light lines faintly colored.	Light line faintly colored.	No reaction.	Cuticularized layer brown. Light line faintly brown.	Cuticularized layer made up of cellulose. Light line, cellulose in part.
Medicago sativa.	Conical cuticularized layer colors blue rapidly. Light lines blue, lighter than remainder of wall. Cuticle unchanged.	Cuticle no change. Cuticularized conical layer blue. Light lines a light blue, lighter than cell-wall. Disintegration except cuticle.	No reaction.	Cuticle does not swell.		No reaction for cuticle. The cuticularized layer stains but slightly.	No reaction.	Cuticularized layer and light line faintly brown.	Cuticularized layer made up of cellulose. Light line cellulose in part.

TABLE C.—MICROCHEMICAL REACTIONS OF OSTEOSCLERIDS.

Name of Species.	Chloriodide of Zinc.	Sulphuric Acid and Iodine.	Phloroglucin & Hydrochloric Acid.	Chloral Hydrate.	Fuchsine.	Haematoxylin.	Ferric Chloride.	Iodine.	Chemical Composition.
Astragalus canadensis.	Walls color blue. Plastic material brown.	Walls color light blue. Rapidly disintegrated.	No reaction.	Swell and become clear.	Cell-walls color slightly, contents deeper.		Color bluish, turns black.	Contents color brown, walls less than chromatophores	Tannin present. Walls made up of cellulose.
Baptisia leucophaea.	Walls only slightly blue colored.	Walls only slightly blue colored. Rapidly disintegrated.	Upper walls colored a light shade of red.	Swell and become clear.	Cell-walls color slightly, contents deeper.		Color bluish, turns black.	Contents color brown.	Tannin present. Cell-walls partially lignified.
Tephrosia virginiana.	Walls color blue.	Walls color blue. Striae evident. Disintegrated.	No reaction.	Swell and become clear.	Cell walls but slightly colored, contents deeper.		Brightly colored, turns blackish.	Contents color brown.	Tannin present. Walls made up of cellulose.
Vicia Faba.	Walls color blue.	Walls color blue. Disintegrated.	No reaction.	Swell and become clear.	Contents color deeper than walls.		Deeply colored especially in hilar region, bluish, becomes black.	Contents color brown.	An abundance of tannin. Walls made up of cellulose.

TABLE D.—MICROCHEMICAL REACTIONS OF NUTRIENT LAYER.

NAME OF SPECIES.	ALCANNIN.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	PHLOROGLUCIN & HYDROCHLORIC ACID.	CHLORAL HYDRATE.	FUCHSINE.	HAEMATOXYLIN. DELAFIELD.	FERRIC CHLORIDE.	IODINE.	NORMAL COLOR, AND CHEMICAL REACTIONS SHOW
Petalostemon candidus.	None.	Walls color blue but more slowly than Malpighian cells. Vascular elements not colored blue.	Walls color blue except vascular elements. Rapid disintegration.	Vascular elements colored light shade of red, especially tracheid island.	Swells and becomes clear.	Walls color, contents more deeply.		Colors bluish, becoming blackish.	Contents color rapidly.	Tannin abundant. Walls consist of cellulose except vascular elements. Normally of a brownish color.
Coronilla montana.	None.	Walls color blue.	Walls color light blue. Rapid disintegration.	No reaction except vascular elements.	Swells and becomes clear.	Walls color, contents more deeply.	Walls color but slightly.	Colors bluish, becoming blackish.	Contents color brownish.	Vascular elements lignified. Walls consist of cellulose. Normally cells colored brownish. Tannin abundant.
Gleditschia triacanthos.	None.	Cell-walls do not color rapidly, and only slightly.	Cell-walls color blue but slightly, rapidly disintegrate.	Sclerenchyma cells slightly colored a light shade of red, also vascular elements.	Swells but little, becomes clear.	Walls but slightly colored, much less than Malpighian cell.		Colors bluish, becoming blackish, the outer and inner parts, most abundantly.	Contents color brown.	Layer brown, contains an abundance of tannin. Walls in part consist of cellulose and in part of lignin.

TABLE E.—MICROCHEMICAL REACTIONS OF COTYLEDONS.

NAMES OF SPECIES.	ALCANNIN.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	PHLOROGLUCIN & HYDROCHLORIC ACID.	CHLORAL HYDRATE.	FUCHSINE.	HAEMATOXYLIN. DELAFIELD.	FERRIC CHLORIDE.	IODINE.	NORMAL COLOR, AND CHEMICAL, REACTIONS SHOW
Cassia marylandica.	Red.	Walls color blue.	Walls color blue. Rapid disintegration.	No reaction.	Aleurone grains broken up.	Aleurone grains colored.		No reaction.	Nucleus colored. Aleurone grains color brownish.	An abundance of protein and fat. Walls consist of cellulose. Tannin absent.
Lespedeza violacea.	Red.	Walls color blue.	Walls color blue. Rapid disintegration.	No reaction.	Aleurone grains broken up.	Aleurone grains colored. Procambial elements first.	Walls color.	No reaction.	Nucleus and aleurone grains color brownish.	An abundance of fat and protein. Walls consist of cellulose. Tannin absent.
Mucana pruriens.	Red.	Walls color blue.	Walls color blue. Rapid disintegration of walls and starch grains.	No reaction.	Aleurone grains broken up. Starch grains swell.	Aleurone grains colored.		No reaction.	Nucleus and aleurone grains color brownish. Starch grains blue.	An abundance of starch, some protein and fat. Walls consist of cellulose. Tannin absent.
Medicago sativa.	Red.	Walls color blue. Starch grains deeply.	Walls color blue. Starch grains blue. Rapid disintegration.	No reaction.	Aleurone grains broken up. Starch grains swell.	Aleurone grains and nucleus color rapidly. Walls resistant.	Contents of cells color more readily than walls.	No reaction.	Nucleus and Aleurone grains color brownish. This reagent alone colors the starch grains very pale blue.	An abundance of fat and protein. Small starch grains. Walls consist of cellulose. Tannin absent.
Tamarindus indica.	Slightly red.	Walls color bluish-black with this reagent. Dissolved.							Aleurone grains color brownish. Cellulose bluish.	Reserve cellulose. protein, and fat present.

TABLE F.—MICROCHEMICAL REACTIONS OF ENDOSPERM.

AME OF PECIES.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	HYDRO-CHLORIC ACID.	POTASSIC HYDRATE	FERRIC CHLORIDE.	IODINE.	PHLORO-GLUCIN & HYDRO-CHLORIC ACID.	WATER.	FUCHSINE.	HAEMATOX-YLIN. DELAFIELD.	CHLORAL HYDRATE.	NORMAL CONDITION, CHEMICAL REACTIONS SHOW
ragalus nadensis.		Cell-walls color blue, rapidly dissolved.	Cell-walls rapidly dissolved.		No reaction.	Contents colored brownish. Cells light straw color.	No reaction.	Becomes mucilaginous, except walls of aleurone cells.	Contents color rapidly. Walls colorless.	Walls of mucilaginous reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless, muco-cellulose. Contents, protein. Tannin absent, also starch.
dicago sativa.	Walls color light blue.	Cell-walls color blue rapidly, walls of aleurone less rapidly. Walls rapidly dissolved.	Walls rapidly dissolved, except primary.	Not changed.	No reaction.	Contents colored brownish. Walls of aleurone cells light straw color,	No reaction.	Becomes mucilaginous, except walls of aleurone cells.	Contents color rapidly. Walls nearly colorless.	Walls of reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless, muco-cellulose. Contents protein. Tannin and starch absent.
ditschia acanthos.	Walls color light blue.	Cell-walls color blue, rapidly dissolved. Protein brown.	Cell-walls rapidly dissolved.	Not changed.	No reaction.	Contents of aleurone cells brownish, conspicuous. Walls light straw color.	No reaction.	Walls of reserve cellulose become mucilaginous.	Contents color. Walls colorless.	Walls of reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless, muco-cellulose. Contents, protein. Tannin and starch absent. Aleurone cells with a large amount of protein.
ronilla montana.	Walls color light blue. Aleurone darker. Long continued action causes middle lamella to color blue.	Walls color light blue, rapidly dissolved.	Cell-walls rapidly dissolved.	Not changed.	No reaction.	Aleurone layer conspicuous. Contents brownish. Walls light straw color.	No reaction.	Mucilaginous except walls of aleurone cells.	Aleurone contents deeply colored. Walls colorless.	Walls of reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless. Aleurone cells with a large amount of protein. Tannin and starch absent, muco-cellulose present.

TABLE F.— MICROCHEMICAL REACTIONS OF ENDOSPERM. — *Continued.*

NAME OF SPECIES.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	HYDRO-CHLORIC ACID.	POTASSIC HYDRATE.	FERRIC CHLORIDE.	IODINE.	PHLORO-GLUCIN & HYDRO-CHLORIC ACID.	WATER.	FUCHSINE.	HAEMATOX-YLIN. DELAFIELD.	CHLORAL HYDRATE.	NORMAL CONDITION, CHEMICAL REACTIONS SHOW
Tephrosia virginiana.	Walls of aleurone layer color blue rapidly. Reserve cellulose light blue.	Walls of aleurone layer blue. Reserve cellulose light blue. Rapidly dissolved.	Cell-walls rapidly dissolved.	Not changed.	No reaction.	Contents color brownish. Aleurone layer conspicuous. Walls light straw color.	No reaction.	Mucilaginous except walls of aleurone cells.	Contents color rapidly, in strong contrast with walls.	Walls of reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless. Aleurone cells with a large amount of protein. Muco-cellulose. Tannin and starch absent
Lespedeza violacea.	Walls of aleurone layer color blue rapidly. Reserve cellulose light blue. Middle lamella after long continued action blue.	Walls color light blue. Rapidly dissolved, except middle lamella.	Cell-walls rapidly dissolved.	Not changed.	No reaction.	Walls of aleurone cells light straw color. Contents brownish, Reserve cellulose. Walls light straw color.	No reaction.	Becomes mucilaginous, except walls of aleurone layer.	Contents of aleurone layer conspicuously colored.	Aleurone layer deeply colored. Walls of reserve cellulose not colored. Contents of reserve cellulose cells slightly colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless. Aleurone cells with a large amount of protein. Muco-cellulose. Tannin and starch absent.

TABLE G.— RELATION OF THE STRUCTURES OF THE CELLS OF THE COTYLEDON TO GERMINATION.

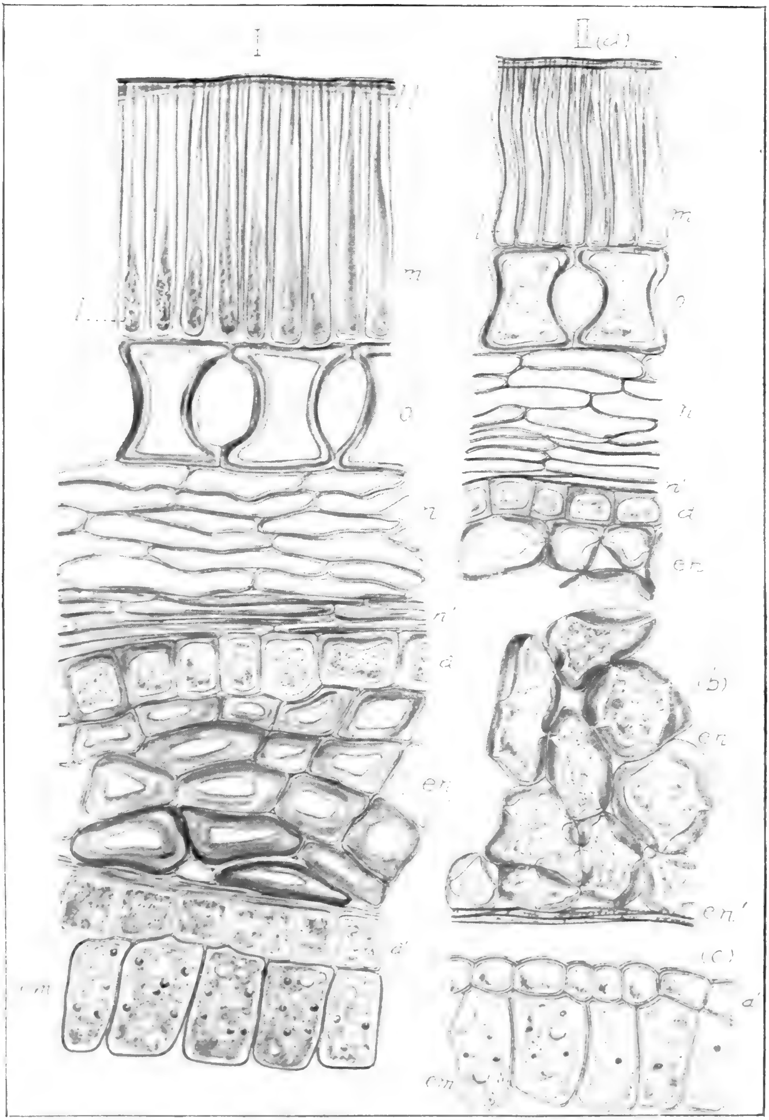
NAME OF SPECIES.	KIND OF CELLS, SUPERIOR FACE OF COTYLEDON.	KIND OF CELLS, INFERIOR FACE OF COTYLEDON, WITH CONTENTS.	KIND OF GERMINATION.	REFERENCES TO GERMINATION STUDIES.
Baptisia leucantha. " *leucophaea.*	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	Epigaeous.	De Candolle: *B. australis*, 84. *pl. 4. f. 4.*
Sophora sericea.	Several rows of palisade cells.	Parenchyma cells loosely arranged, small starch grains.	"	De Candolle: *S. japonica*, 83. *pl. 4. f. 1.*
Genista tinctoria.	Palisade cells, three to four rows.	Parenchyma loosely arranged, starch absent.	"	De Candolle: Sp. 80. *pl. 5. f. 6.* Lubbock, 409.
Lupinus pusillus.	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	"	De Candolle: *L. angustifolia*, 107. *pl. 18. f. 94;* Lubbock. *L. arboreus*, 405. *f. 264;* *L. micranthus*, 406; *L. sulphureus*, 406.
" *luteus.*	One well-developed row of palisade cells.	Parenchyma cells larger, loosely arranged, starch absent.		
Medicago sativa.	Several rows of palisade cells.	Parenchyma cells loosely arranged, small starch grains present.	"	De Candolle: Sp. 88. *pl. 7. f. 15.* Lubbock: *M. orbiculatus*, 415. *f. 271;* *M. lupulina*, 415; *M. sativa*, 415.
Melilotus alba.	Several rows of palisade cells.	Parenchyma cells loosely arranged, small starch grains present.	"	Hitchcock: Bull. 50. 27. *f. 20.*
Hosackia Purshiana.	Two rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	"	Lubbock: *Lotus Tetragonolobus*, 419; *Anthyllis vulneraria*, 418. *f. 273.*
Psoralea melilootsoides	Palisade cells, three or four rows.	Parenchyma loosely arranged, wider than palisade cells, starch absent.	"	De Candolle: *P. lathyrifolia*, 89. *pl. 7. f. 21;* *P. verrucosa*, 89. *pl. 7. f. 22.* Lubbock: Sp. 420.

TABLE G.—RELATION OF THE STRUCTURES OF THE CELLS OF THE COTYLEDON TO GERMINATION.—*Continued.*

NAME OF SPECIES.	KIND OF CELLS, SUPERIOR FACE OF COTYLEDON.	KIND OF CELLS, INFERIOR FACE OF COTYLEDON, WITH CONTENTS.	KIND OF GERMINATION.	REFERENCES TO GERMINATION STUDIES.
Indigofera leptosepala.	Three or four rows of palisade cells.	Parenchyma cells somewhat longer than broad, loosely arranged, starch absent.	Epigaeous.	De Candolle: 90. *pl. 7. f. 25.* Lubbock: *I. australis,* 420. *f. 274.*
Coronilla montana.	Palisade cells, two or three rows.	Parenchyma cells loosely arranged, starch absent.	"	De Candolle: 98. *pl. 12. f. 56-57.* Lubbock. *C. juncea,* 430; *Hedysarum denticulatum,* 431. *f. 279; H. coronarium,* 432. *f. 281.*
Desmodium Dillenii. " *canescens.*	Several rows of palisade cells.	Parenchyma cells with inter-cellular spaces, starch absent.	"	Hitchcock: *D. illinoense,* Bull. 50. 27. *f. 24.* Lubbock: *D. canadense,* 436. De Candolle: 100. *pl. 12-13. f. 53-68;* germination of nine species.
Lespedeza violacea.	Palisade cells, two to three rows.	Parenchyma cells with inter-cellular spaces, starch absent.	"	Holm: 67. *pl. 9. f. 43-44; L. procumbens, pl. 9. f. 45-46.* Lubbock: *L. angustifolius,* 437. De Candolle: 101. *pl. 14. f. 73.*
Stylosanthes elatior.	Palisade cells compactly arranged.	Parenchyma cells loosely arranged, starch absent.	"	
Vicia Faba. " *americana.*	Palisade cells absent.	Large parenchyma cells, contain starch.	Hypogaeous.	De Candolle: *Vicia,* 102. *f. 74-76.* Marek: 160, 167. . *69, 72-74.* Malpighi: 100. *f. 3.*
Lathyrus odoratus. " *sativus.*	" "	Large loosely arranged parenchyma cells, starch present.	"	De Candolle: 103. *pl. 15.* Lubbock: *L. Nissolia,* 437. *f. 284; L. Aphaca,* 439. *f. 285.*
Pisum sativum.	" "	Large parenchyma cells, starch present.	"	Malpighi: 102. *f. 4.* De Candolle: 107. *f. 78.* Marek: 153. *f. 47-53, 59-66.*
Lens esculenta.	" "	Large parenchyma cells, starch present.	"	De Candolle: 103. *pl. 15. f. 77.*
Phaseolus perennis " *vulgaris*	" "	Large parenchyma cells, starch present.	Epigaeous.	Lubbock: *P. vulgaris,* 446. *f. 290.* Malpighi: *98. f. 2.*

TABLE G.— RELATION OF THE STRUCTURES OF THE CELLS OF THE COTYLEDON TO GERMINATION.—*Continued.*

NAME OF SPECIES.	KIND OF CELLS. SUPERIOR FACE OF COTYLEDON.	KIND OF CELLS, INFERIOR FACE OF COTYLEDON, WITH CONTENTS.	KIND OF GERMINATION.	REFERENCES TO GERMINATION STUDIES.
Vigna lutea.	Palisade cells absent.	Large parenchyma cells, starch present.	Epigaeous.	Lubbock: 447.
Strophostyles angulosa.	" "	Large parenchyma cells, starch present.	"	Hitchcock: *Strophostyles pauciflorus*, Bull. 50. 27. *f. 25.*
Amphicarpaea Pitcheri.	" "	Large parenchyma cells, starch absent.	Hypogaeous.	Hitchcock: Bull. 50. 27. *f. 18.*
Cercis canadensis.	Several rows of palisade cells.	Parenchyma loosely arranged, starch absent.	Epigaeous.	Lubbock: *C. Siliquastrum*, 465. *f. 304.*
Cassia marylandica.	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	"	De Candolle: Sp. *pl. 25. f. 115–119.* Lubbock: *C. circinata.* 459. *f. 299; C. obovata*, 460. *f. 300; C. Fistula*, 461. *f. 301–302.* Hitchcock: *C. Chamaecrista*, Bull. 50. 27. *f. 19.*
Gymnocladus canadensis.	Palisade cells absent.	Parenchyma cells large, starch absent.		
Gleditschia triacanthos.	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	Epigaeous.	Tubeuf: 127. *f. 173.* De Candolle: 117. *pl. 22. f. 109.*
Prosopis juliflora.	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.		



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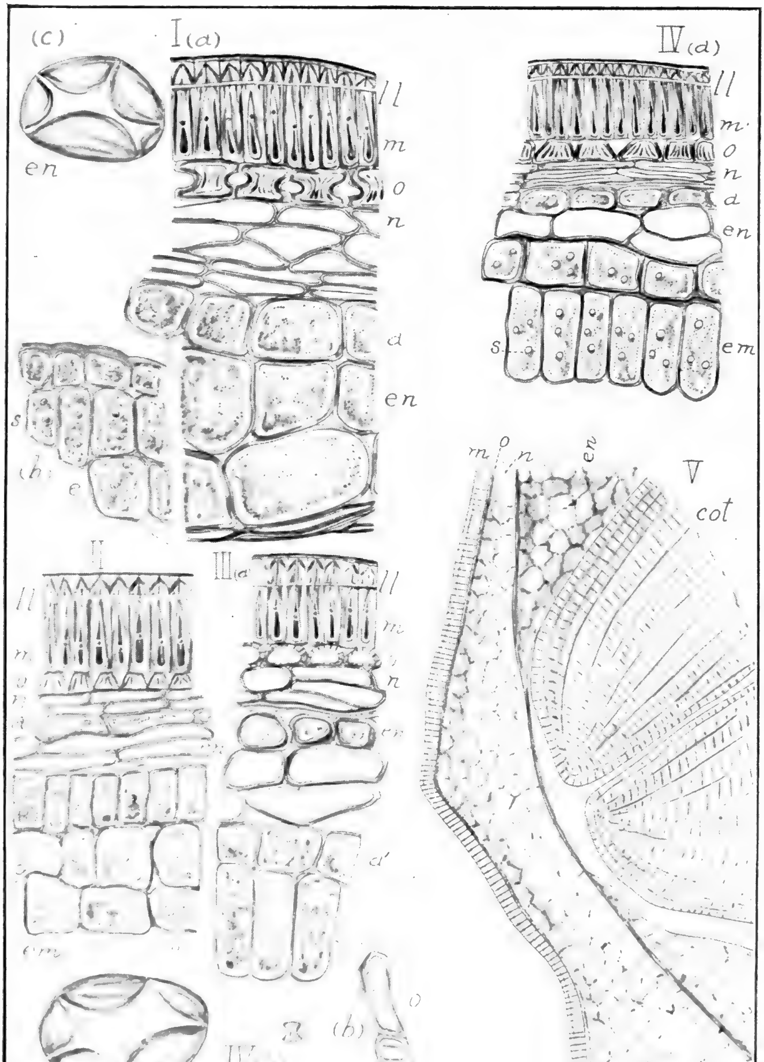

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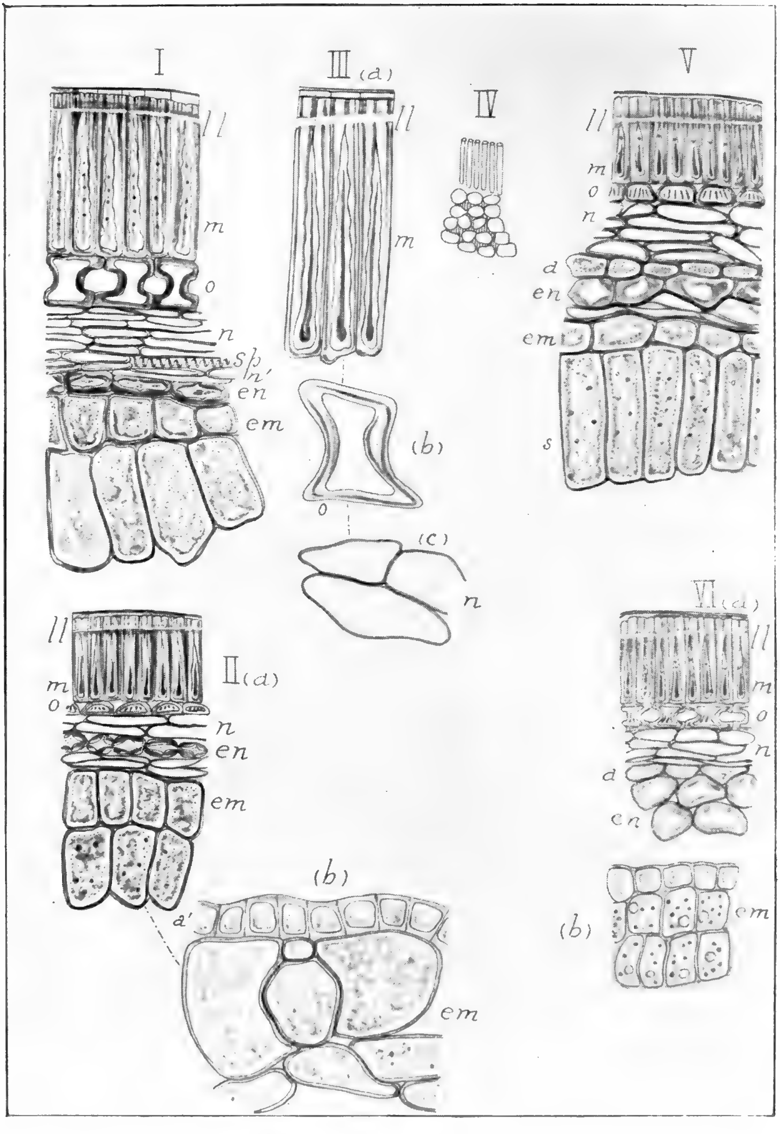

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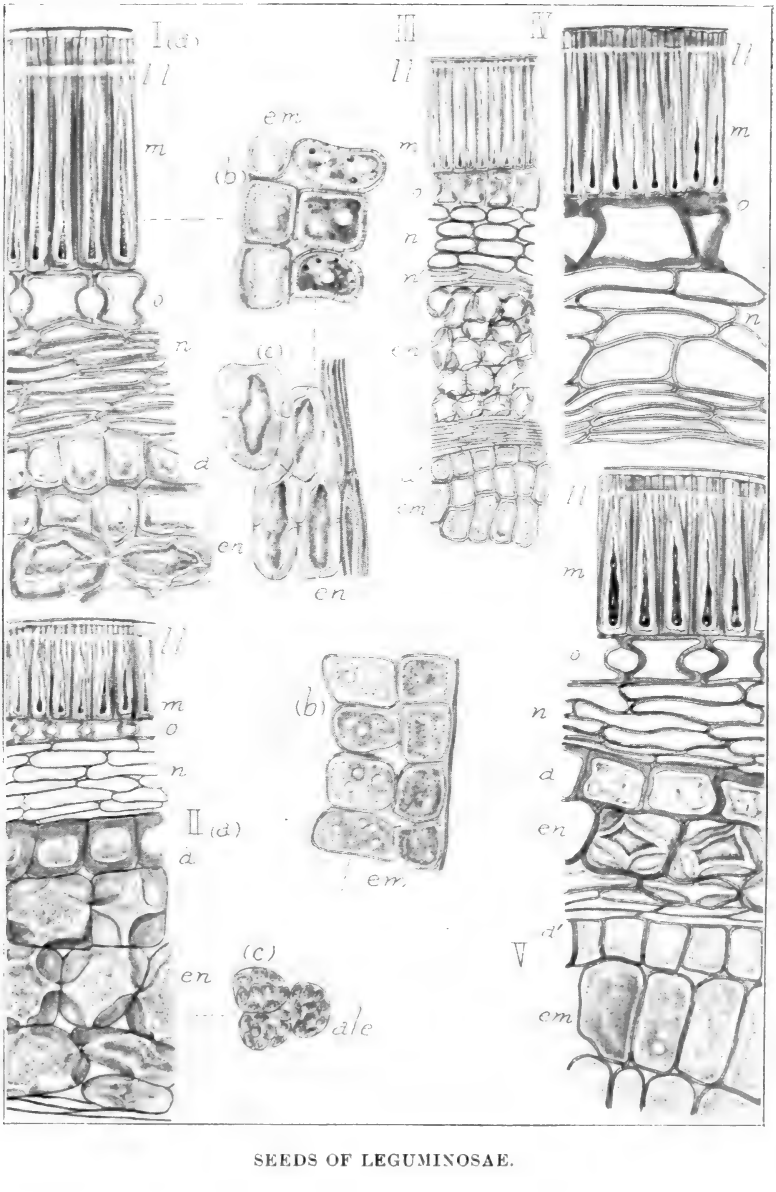

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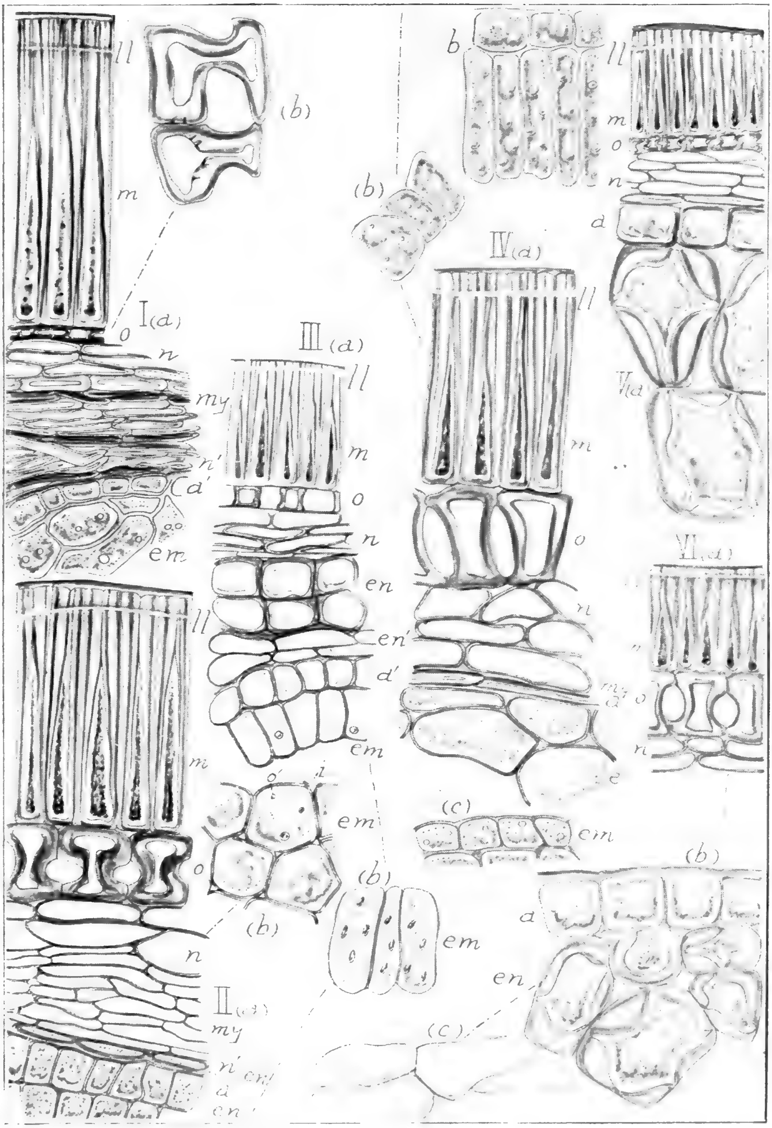

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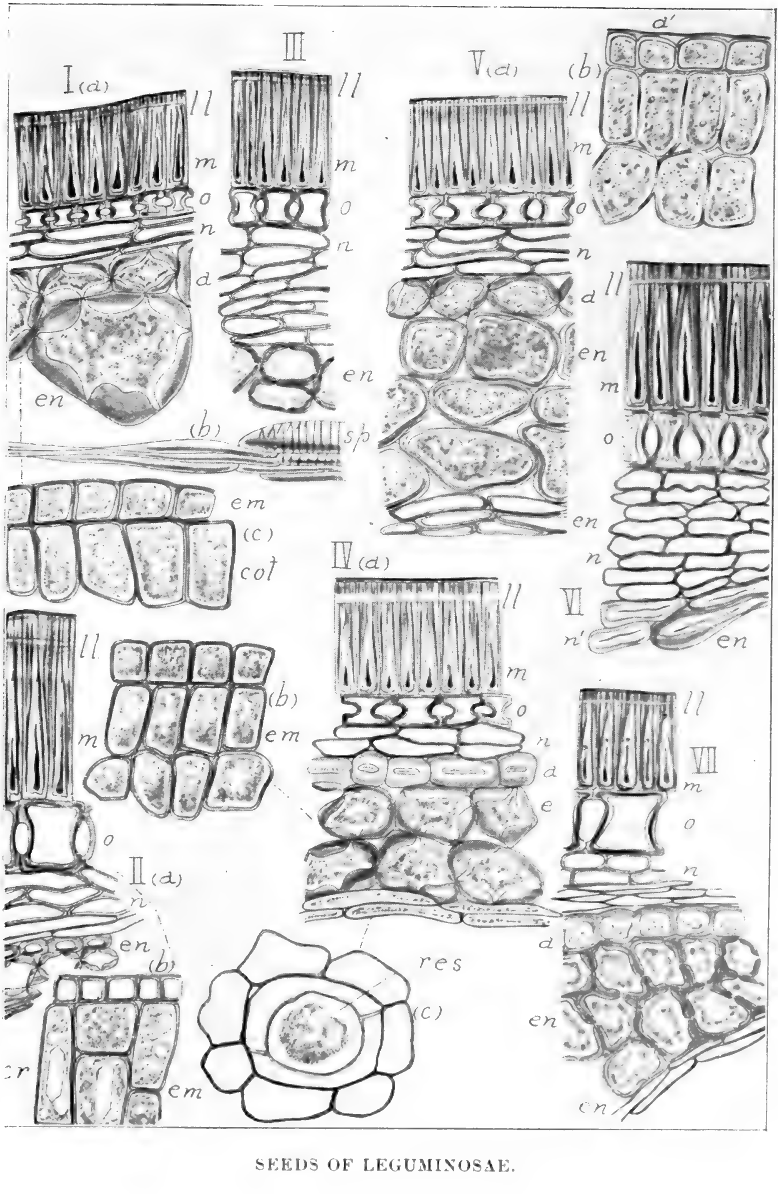

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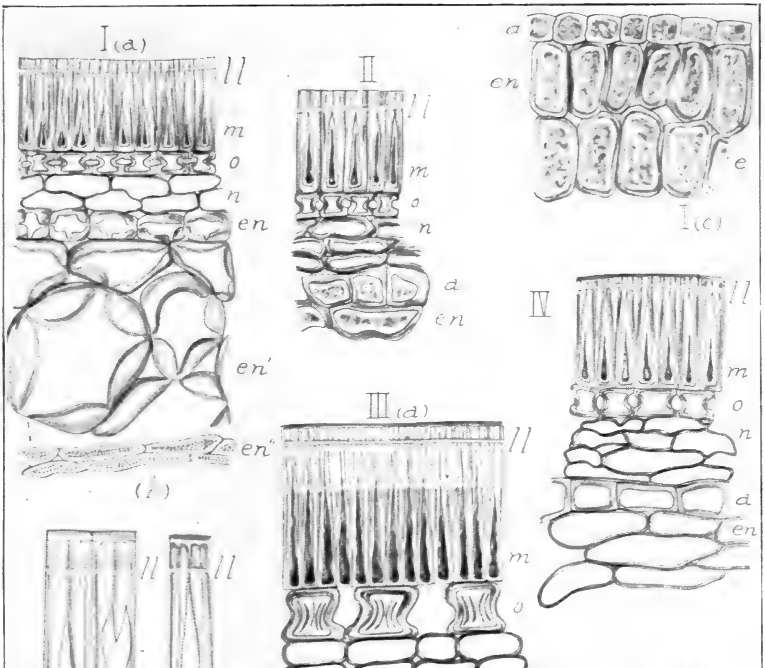

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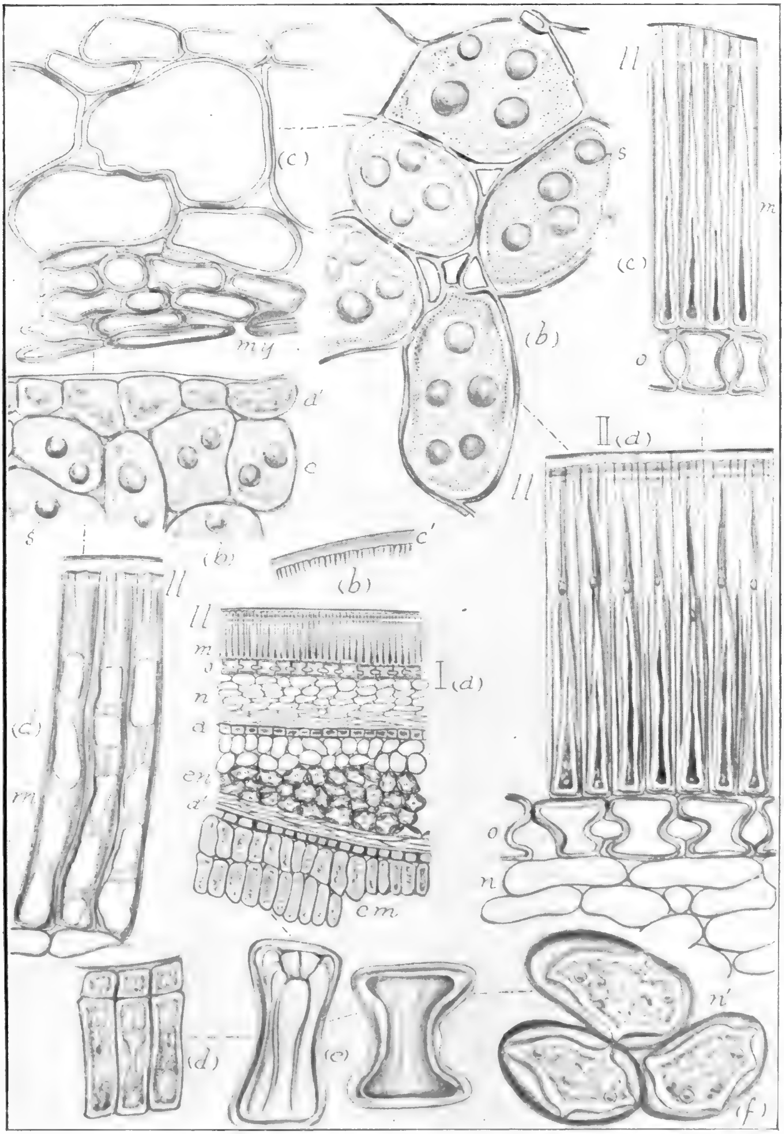

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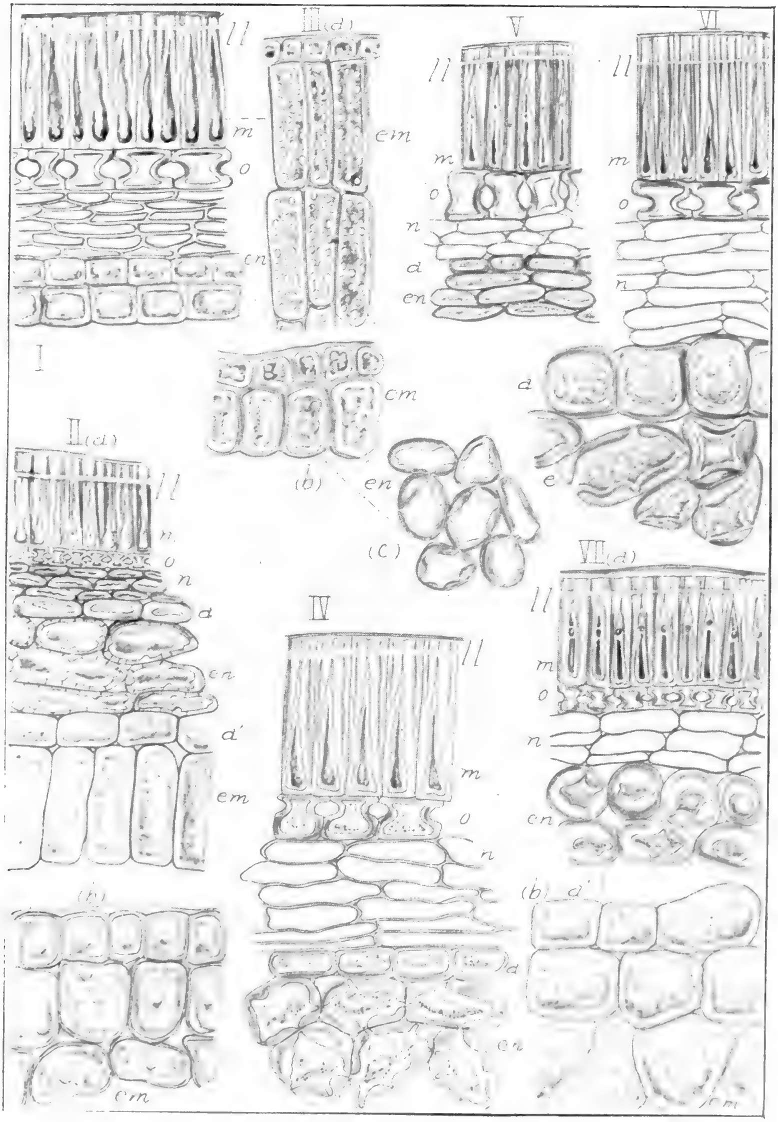

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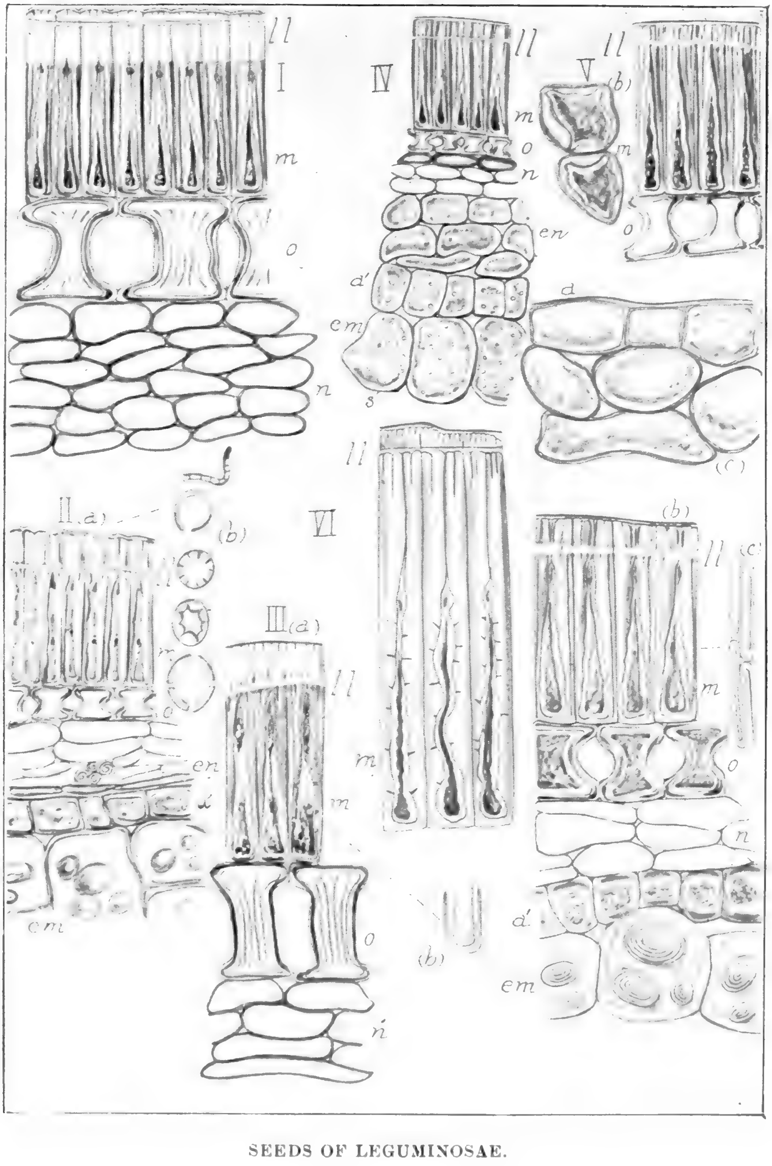

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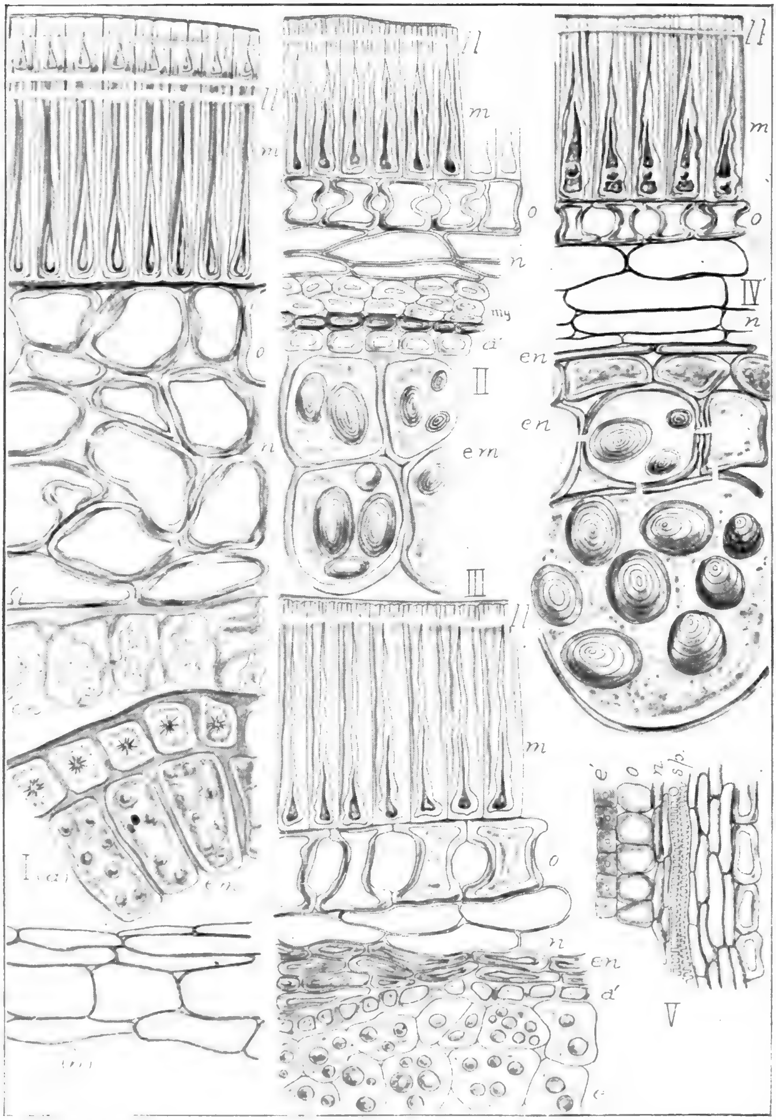

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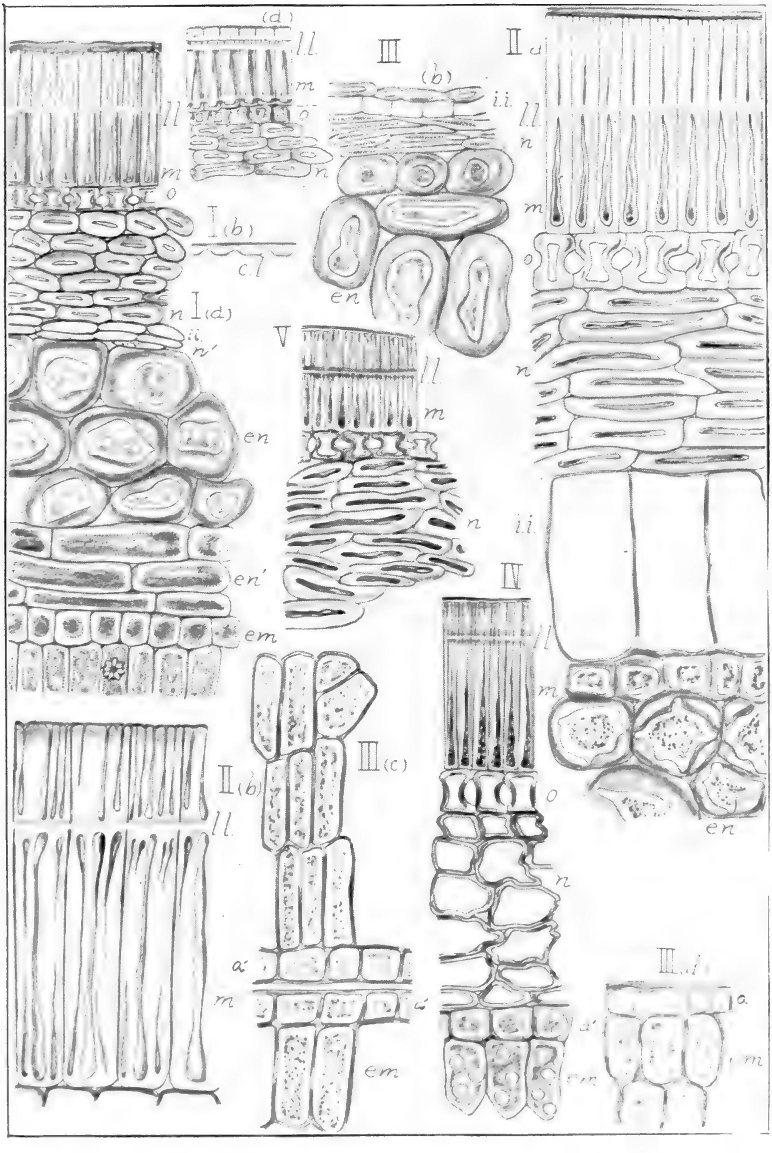

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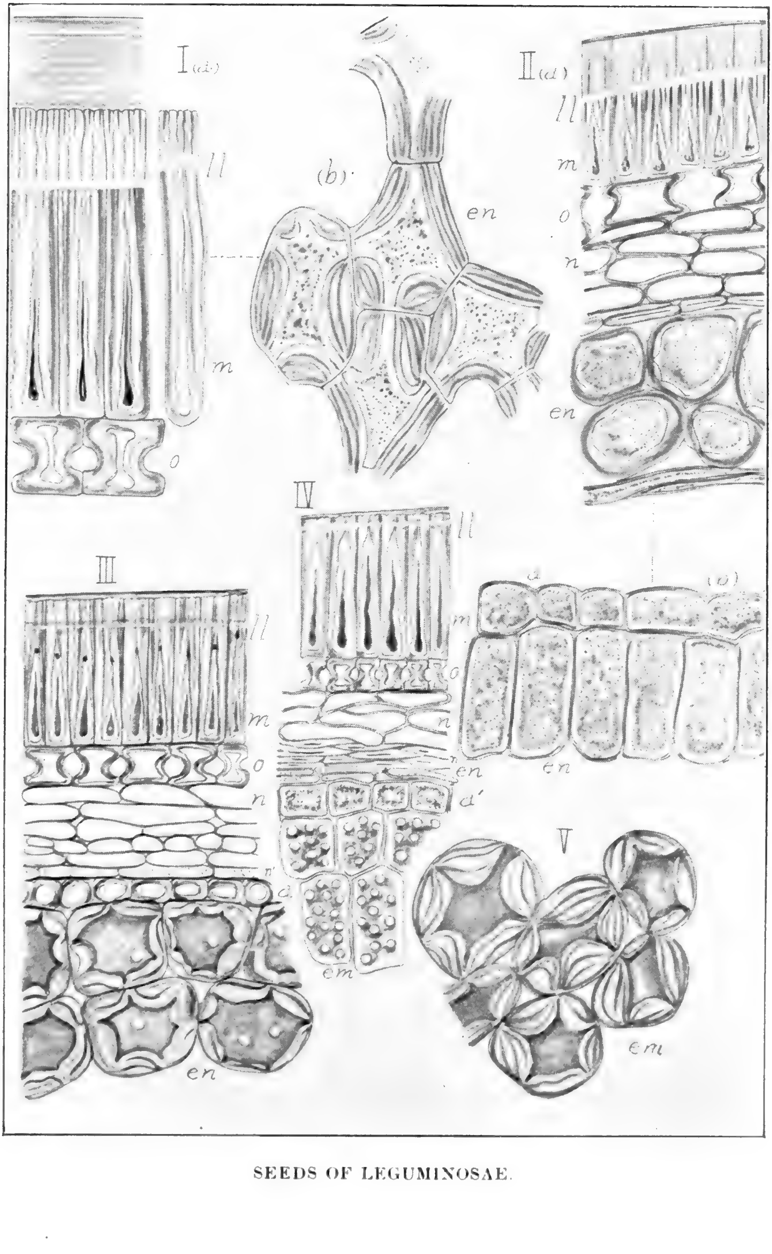

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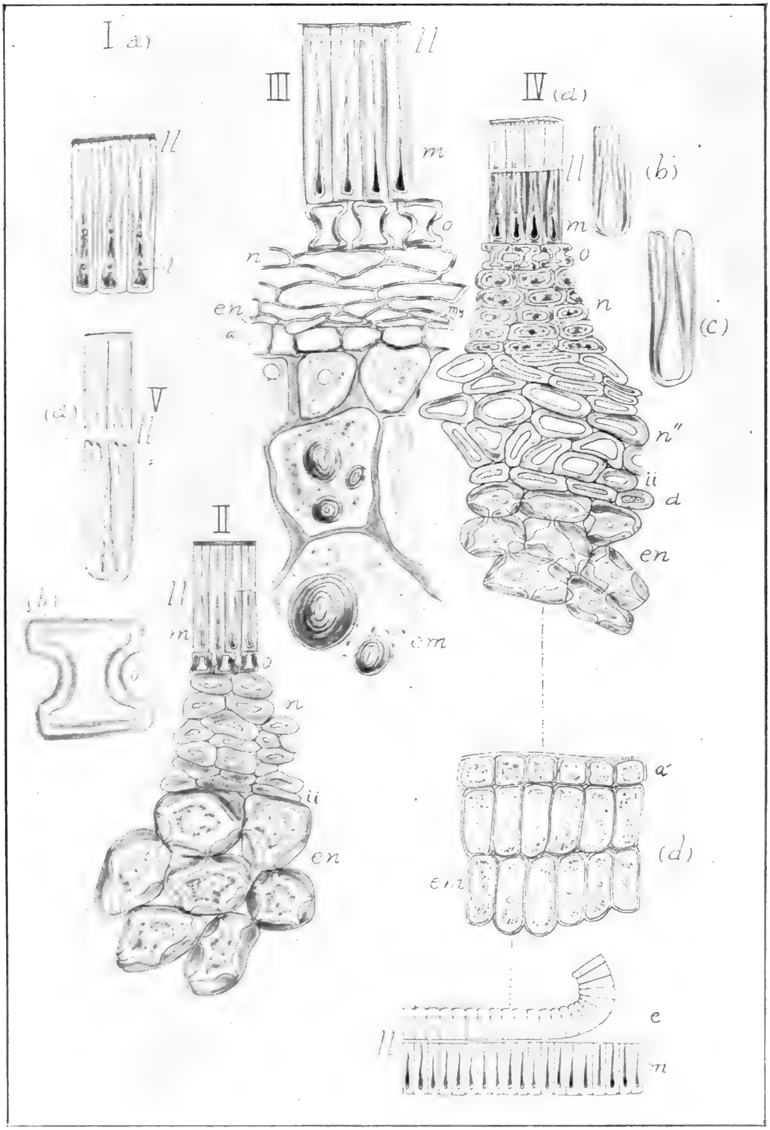

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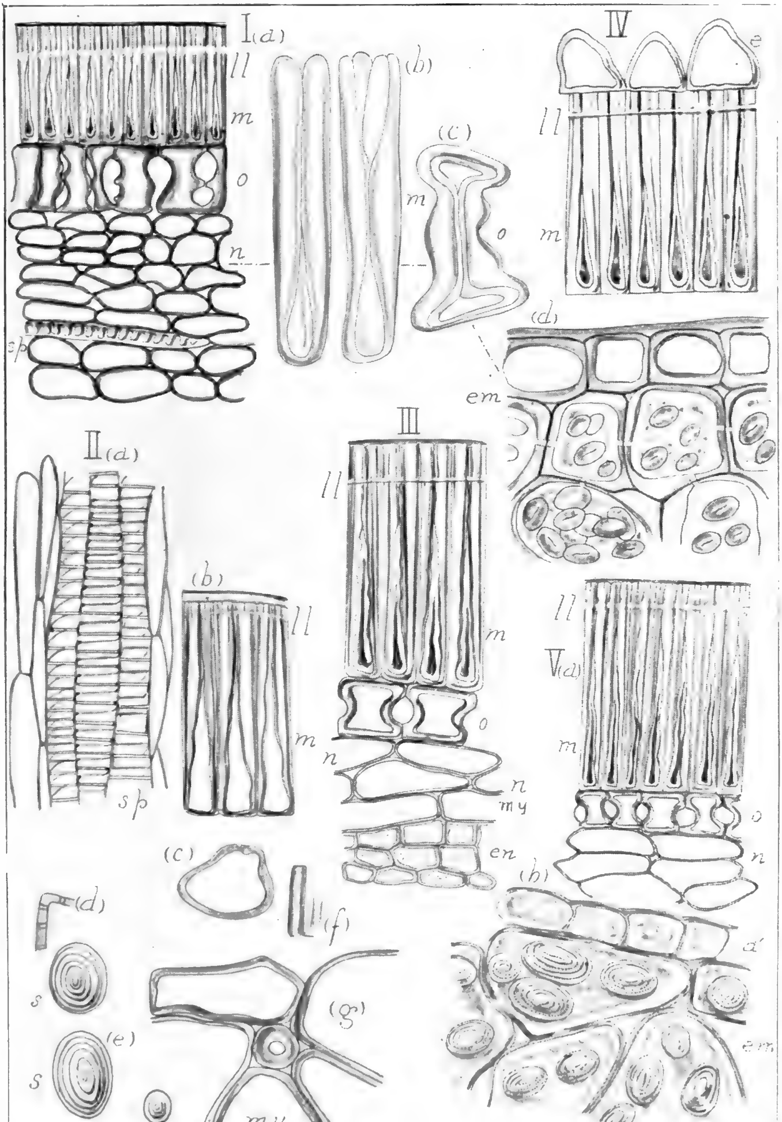

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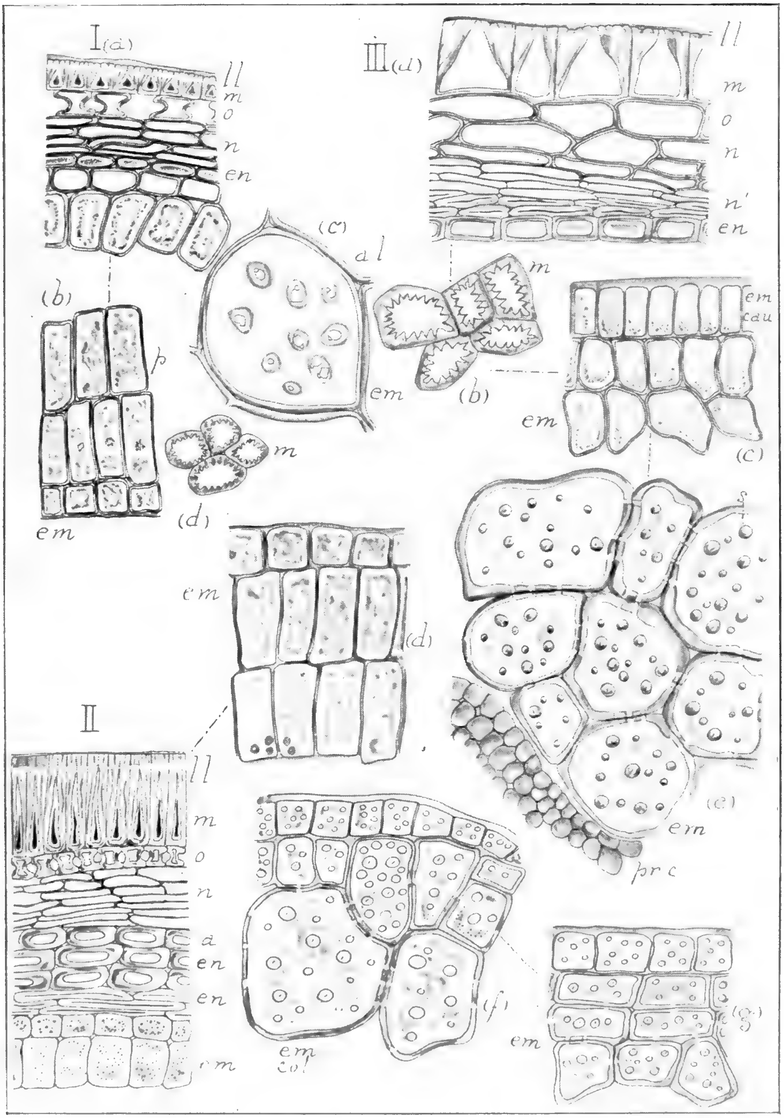

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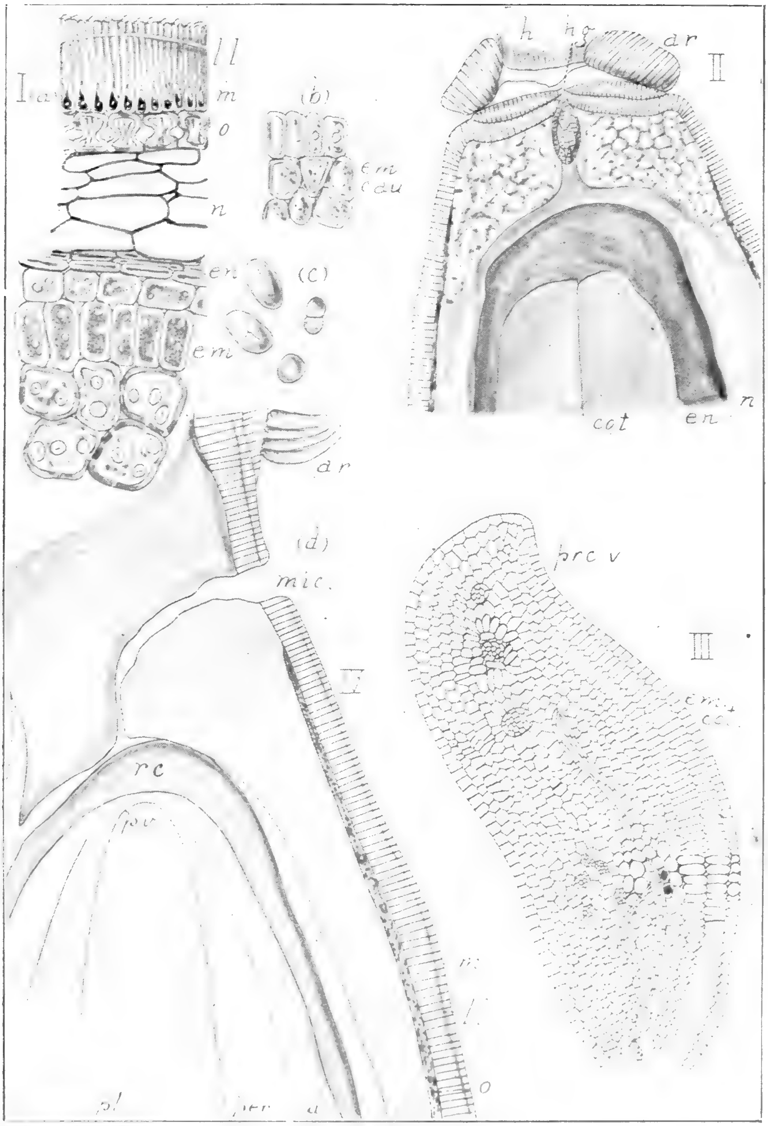

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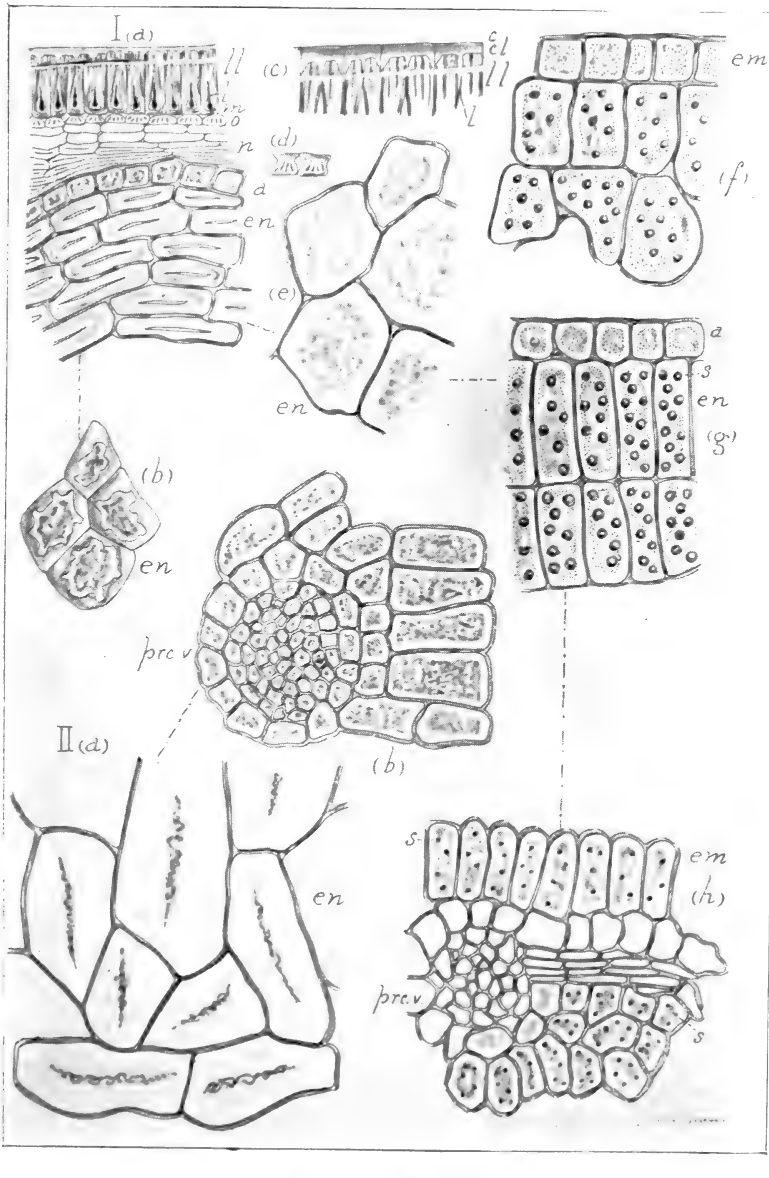

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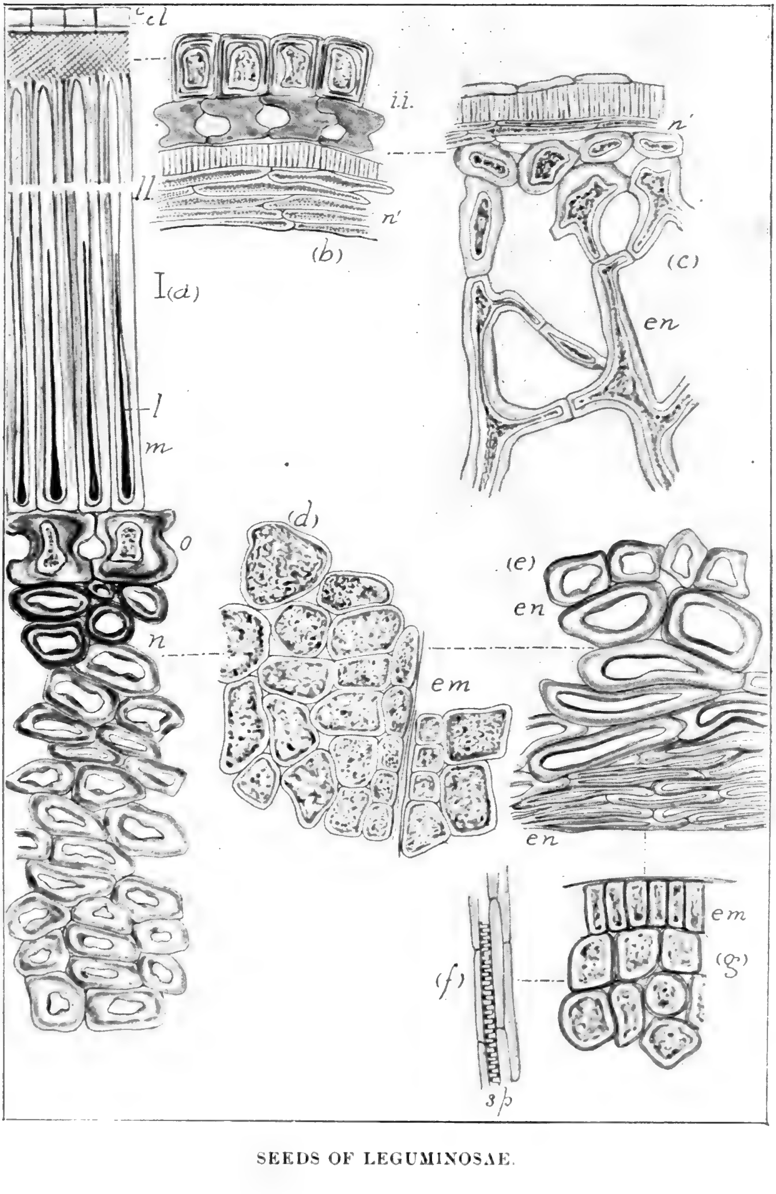

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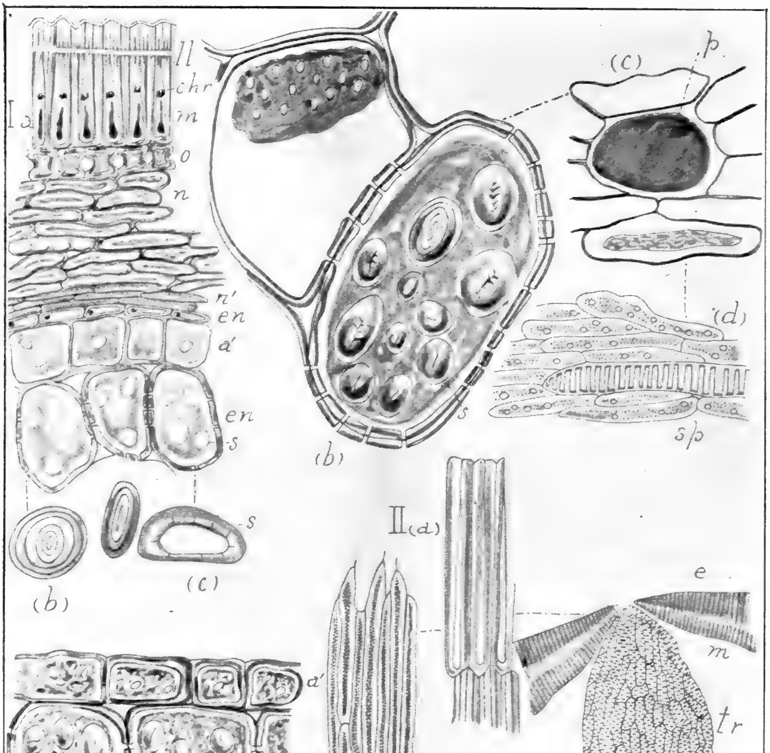

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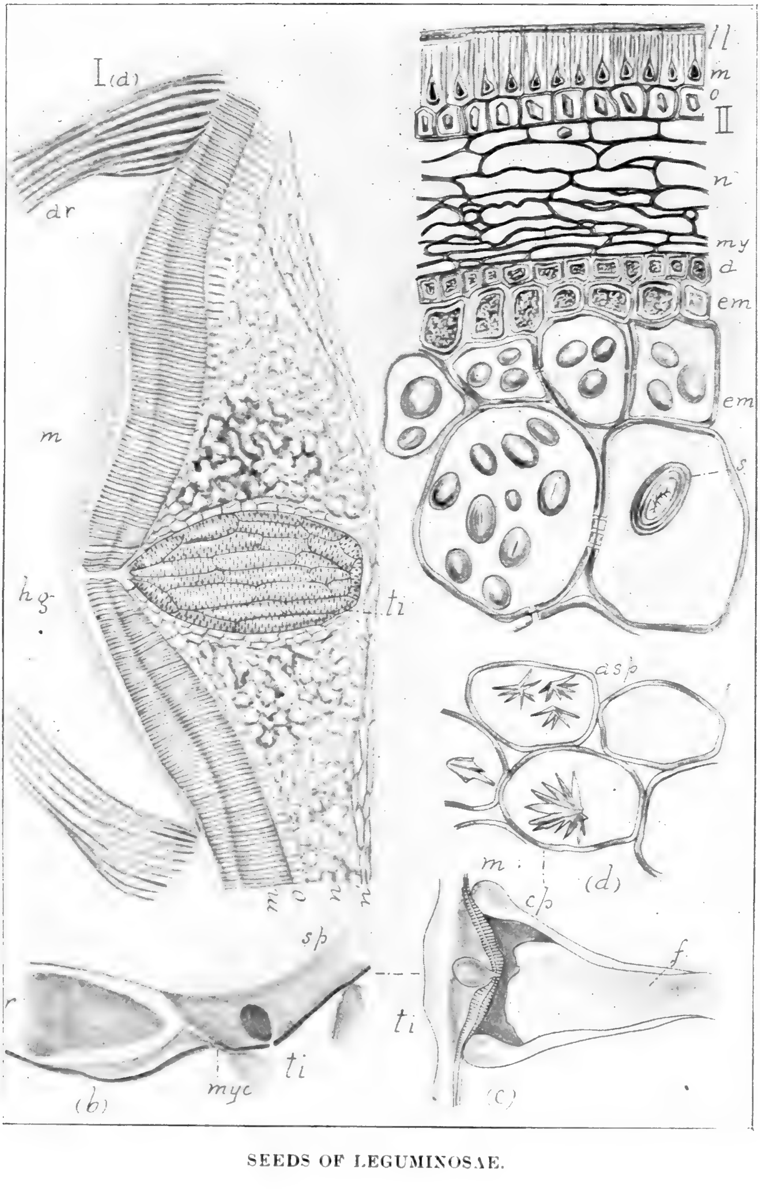

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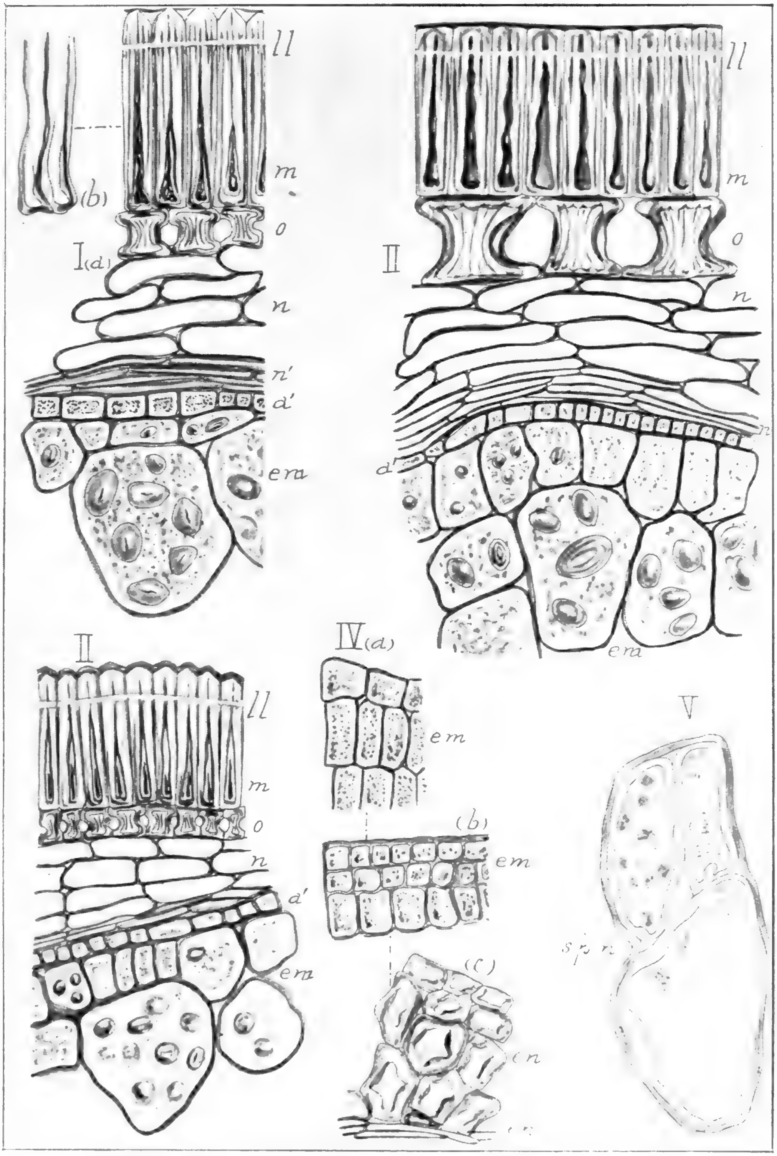

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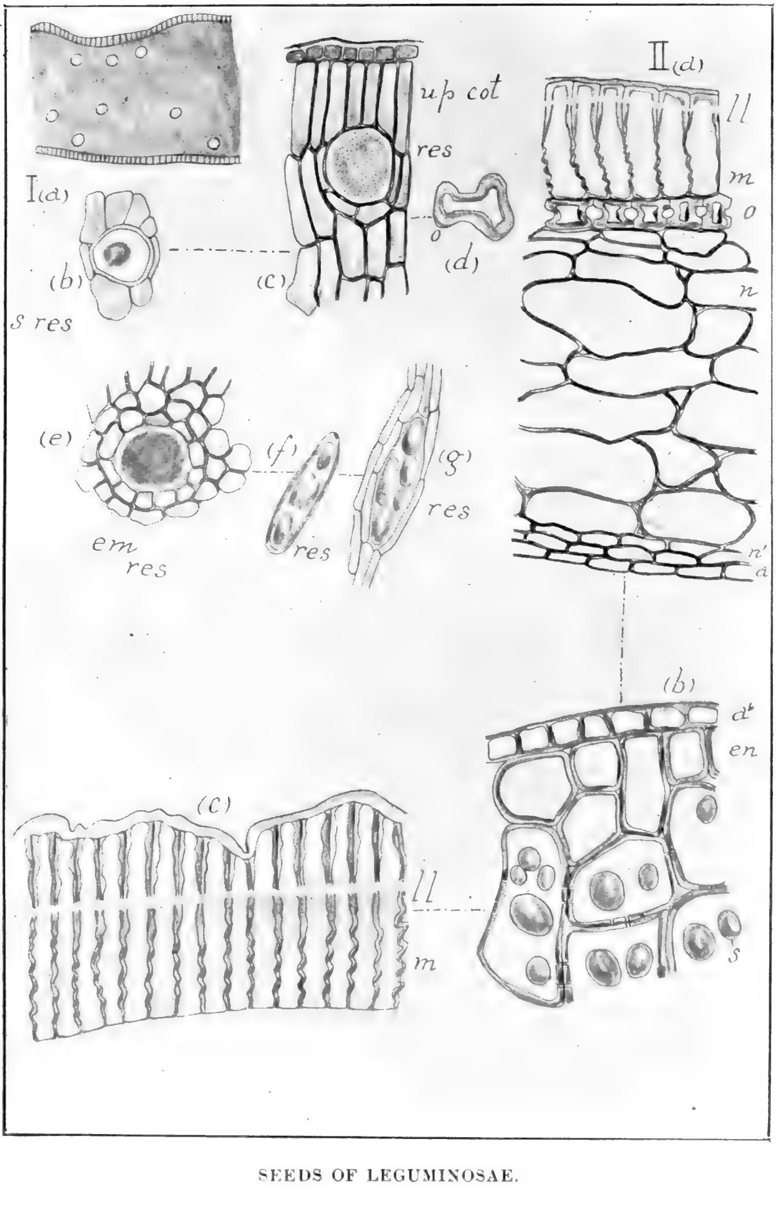

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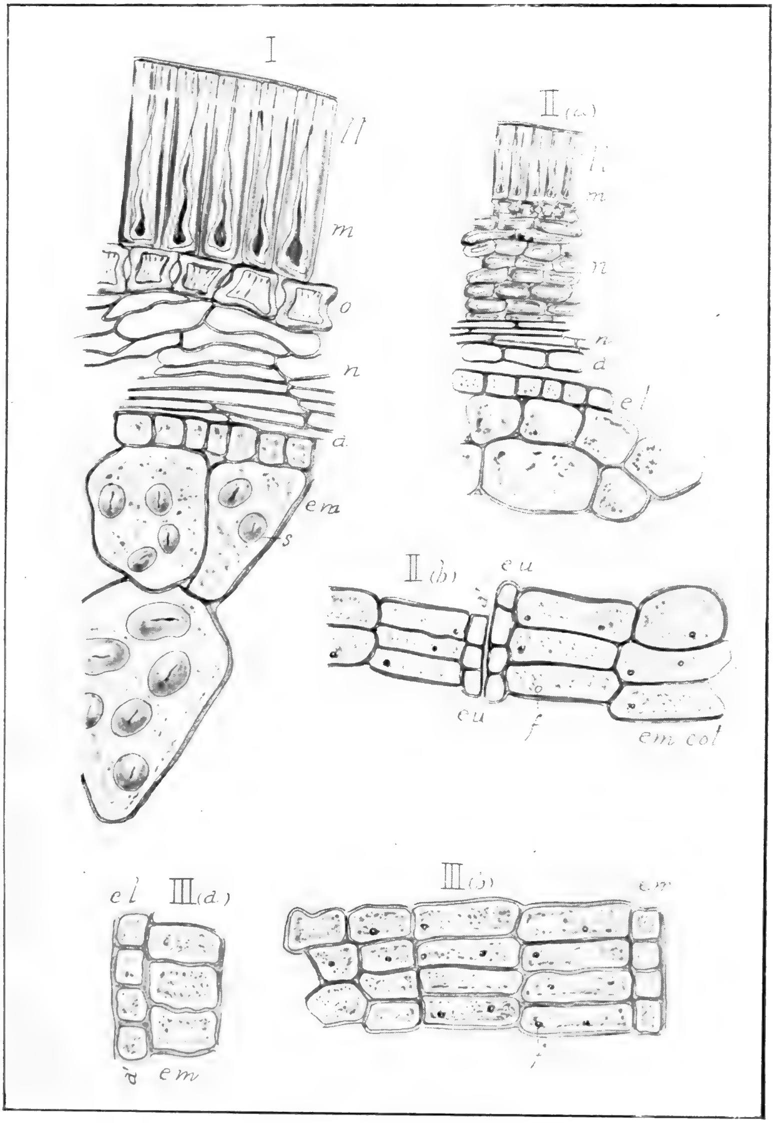

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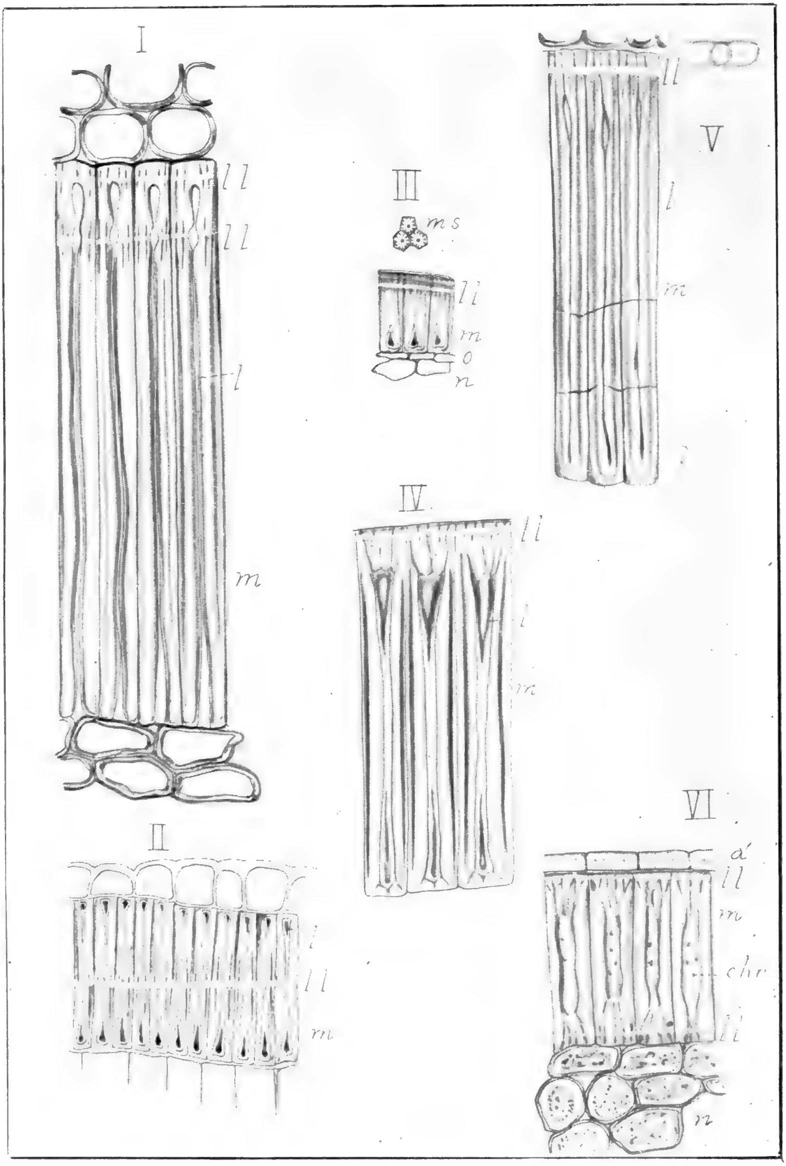

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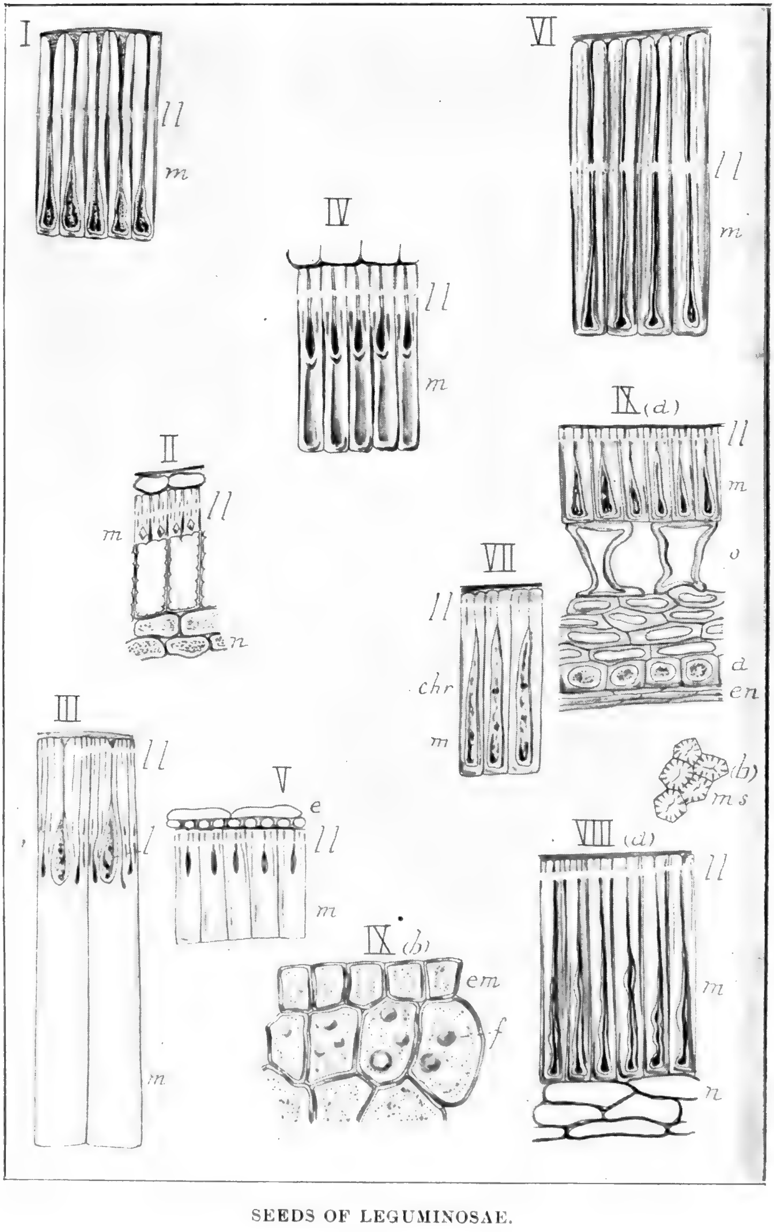

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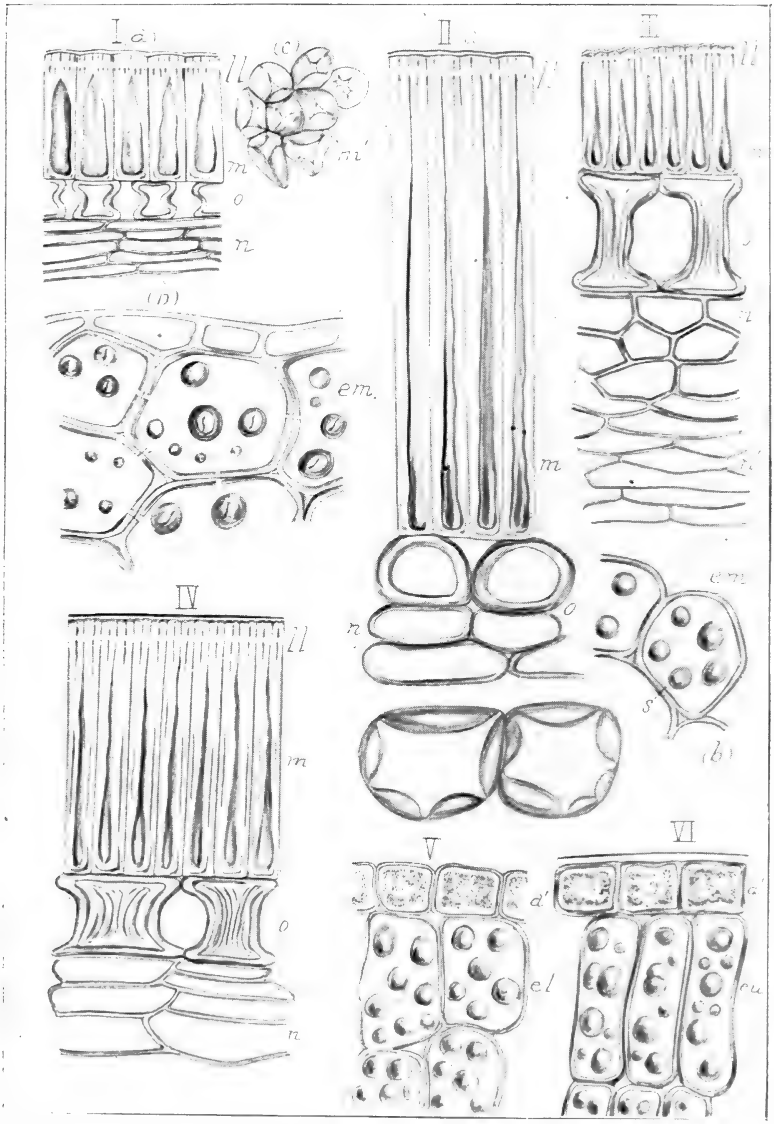

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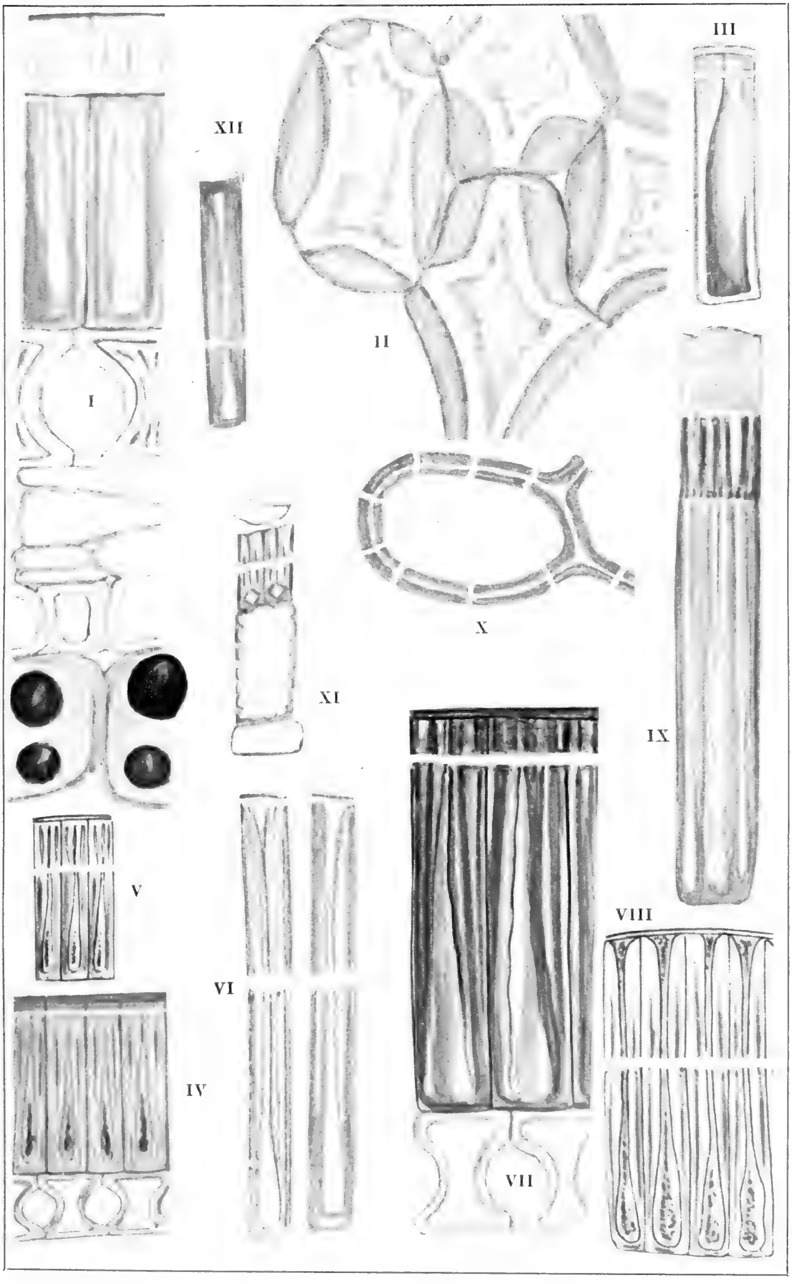

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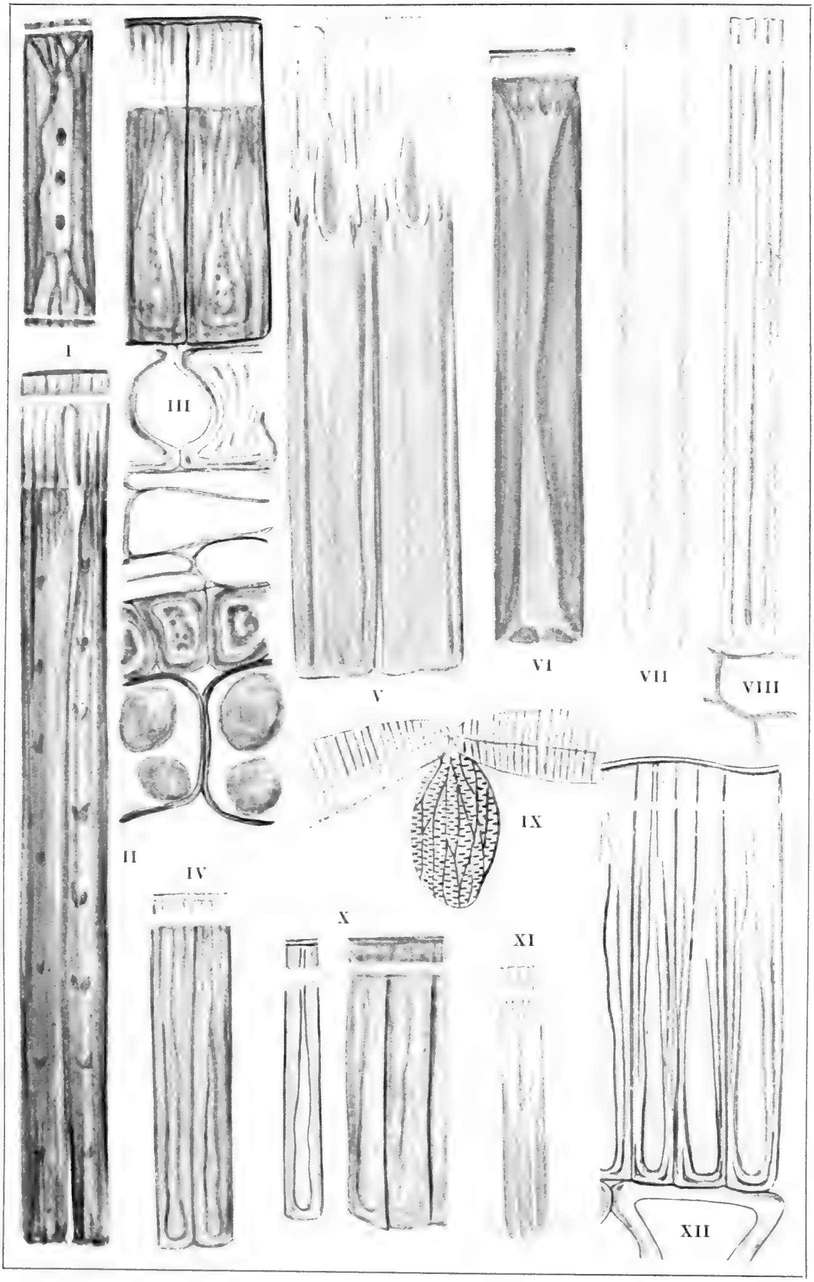

SEEDS OF LEGUMINOSAE.

ON TEMPERATURES IN GASEOUS NEBULAE.

FRANCIS E. NIPHER.

In a former paper in these Transactions,* the author has discussed the conditions in a gravitating nebula having uniform temperature throughout its mass. The present paper deals with the same subject, on the assumption that the initial temperature diminishes from the center outwards, in accordance with the following equation:—

$$T = \frac{T_0 R_0^n}{R^n}. \qquad (1)$$

The condition assumed in the former paper was therefore a special case in which $n = 0$ or $T = T_0 =$ constant.

Let K represent the gravitation constant, M the mass internal to the sphere of radius R, P the pressure at the surface of the same sphere, where the density of the gas is δ, then

$$\frac{dP}{dR} = -k \frac{M}{R^2} \delta. \qquad (2)$$

The equation for a perfect gas gives

$$\delta = \frac{P}{CT}. \qquad (3)$$

By substituting (1) and (3) in (2) and solving for M,

$$M = -\frac{C T_0 R_0^n R^{2-n}}{kP} \frac{dP}{dR}. \qquad (4)$$

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By differentiation of (4)

$$\frac{dM}{dR} = -\frac{CT_0R_0^n}{k}\left[\frac{R^{2-n}}{P}\frac{d^2P}{dR^2} + (2-n)\frac{R^{1-n}}{P}\frac{dP}{dR} - \frac{R^{2-n}}{P^2}\left(\frac{dP}{dR}\right)^2\right]. \quad (5)$$

By geometry and after substitution from (3) and (1)

$$\frac{dM}{dR} = 4\pi R^2\delta = \frac{4\pi R^{2+n}P}{CT_0R_0^n}. \quad (6)$$

Equating these values of $\frac{dM}{dR}$ in (5) and (6), and we have the differential equation for pressure as function of radius.

$$\frac{d^2P}{dR^2} + \frac{2-n}{R}\frac{dP}{dR} - \frac{1}{P}\left(\frac{dP}{dR}\right)^2 + \frac{4\pi kP^2R^{2n}}{C^2T_0^2R_0^{2n}} = 0. \quad (7)$$

The solution of this equation is

$$P = (1-n^2)\frac{C^2T_0^2R_0^{2n}}{2\pi kR^{2(1+n)}}. \quad (8)$$

By equations (3) and (1) the density of the gas is therefore

$$\delta = \frac{PR^n}{CT_0R_0^n} = (1-n^2)\frac{CT_0R_0^n}{2\pi kR^{n+2}}. \quad (9)$$

The mass of gas internal to the sphere of radius R is,

$$M = 4\pi\int_0^R R^2\delta dR = 2(1+n)\frac{CT_0R_0^n}{k}R^{1-n} \quad (10)$$

The weight of a gramme at the surface of the sphere is,

$$g = k\frac{M}{R^2} = 2(1+n)\frac{CT_0R_0^n}{R^{n+1}}. \quad (11)$$

By substitution from equation (1) the last four equations become

$$P = (1 - n^2)\frac{C^2T^2}{2\pi kR^2} \tag{12}$$

$$\delta = (1 - n^2)\frac{CT}{2\pi kR^2} \tag{13}$$

$$M = 2\ (1 + n)\frac{CTR}{k} \tag{14}$$

$$g = 2\ (1 + n)\frac{CT}{R}. \tag{15}$$

These are the equations which hold for any point within the mass, T and R being related to each other in the manner defined by (1).

An examination of equation (10) shows that when $T_0R_0^n$ (the temperature where $R = 1$) is constant, n must be less than unity, in order that the distribution may be physically possible. If n is greater than unity, the value of the integral at the lower limit increases, as the value of R determining that limit approaches zero. The mass external to R is then finite, while that internal to R is infinite. When $n < 1$ the reverse is true. This transition is accompanied by a change in the sign of the indefinite integral. The mass is in one case estimated from a zero where $R = \infty$, and in the other, from a zero at the center.

By dividing the value M in (10) by the volume of the sphere, the resulting average density of the spherical mass is found to be $\frac{3}{1-n}$ times the density at the surface, as given by (9). The average density is then,

$$\delta_a = 3\ (1+n)\ \frac{CT_0R_0^n}{2\pi kR^{n+2}}.$$

An n increases from zero and approaches unity, the average density of a spherical mass becomes more and more nearly inversely as the cube of the radius, or $R^3\delta_a$ approaches constancy. Since this is a measure of the mass within a spherical volume, it follows that the condition approached is one in which the mass within a sphere of radius R is the same as that within a sphere of any other radius. The physical interpretation of this is, that the mass within the smaller sphere becomes infinite, and this mass is not increased by the addition of a finite quantity.

At the surface of a sphere of larger radius R_0 at whose surface the temperature is T_0, the equations (12) (13) (14) and (15) become,

$$P_0 = (1 - n^2)\frac{C^2 T_0^2}{2\pi k R_0^2}. \tag{16}$$

$$\delta_0 = (1 - n^2)\frac{C T_0}{2\pi k R_0^2} \tag{17}$$

$$M_0 = 2\,(1 + n)\,\frac{C T_0 R_0}{k} \tag{18}$$

$$g_0 = 2\,(1 + n)\,\frac{C T_0}{R_0}. \tag{19}$$

These are taken as initial values. Assume that the entire mass contracts so as to preserve the same law of distribution of density. Let r_0 and r be any two radii, satisfying the condition

$$\frac{r_0}{r} = \frac{R_0}{R} = \rho,$$

this ratio being the ratio of contraction.

It is required to find the pressure necessary to compress the sphere of gas, whose initial volume is V_0.

The average density of the sphere is $\frac{3}{1-n}$ times the density at its surface.

Hence by the law of gases

$$\frac{3}{1-n}\,P_0 V_0 = \frac{4}{1-n}\,\pi R_0^3\,(1-n^2)\,\frac{C^2 T_0^2}{2\pi k R_0^2}$$

$$= 2\,(1 + n)\,\frac{C^2 T_0^2 R_0}{k} = M_0 C T_0.$$

Let it be assumed that the temperature of each element of mass remains unchanged. After the mass has contracted to volume $V = \frac{4}{3} \pi R^3$, the same equation gives

$$P' \times \frac{4}{1 - n} \pi R^3 = 2 (1 + n) \frac{C^2 T_0^2 R_0}{k}$$

Hence solving for P',

$$P' = (1 - n^2) \frac{C^2 T_0^2 R_0}{2 \pi k R^3} = (1 - n^2) \frac{C^2 T_0^2 \rho}{2 \pi k R^2} \qquad (20)$$

The pressure at this surface of radius R, before contraction took place, is given by (8). The pressure here has by reason of contraction, been multiplied by ρ^{1-2n}.

The density at the same surface is therefore, after contraction,

$$\delta' = (1 - n^2) \frac{C T_0 R_0}{2 \pi k R^3} = (1 - n^2) \frac{C T_0 \rho}{2 \pi k R^2}. \qquad (21)$$

This density is determined by dividing (20) by $C T_0$, or, by dividing the mass M_0 of (18) which now fills a sphere of volume $\frac{4}{3} \pi R^3$, by this volume and by the factor $\frac{3}{1 - n}$. Equation (9) gives the density at this surface of radius R before contraction took place. This density has by the contraction been multiplied by ρ^{1-n}.

The mass within radius R after contraction is given in (18). It is the mass initially within radius R_0. The mass within the same volume, of radius R, before contraction, is given in (10). This mass has also been multiplied by ρ^{1-n}.

The weight of a gramme at this surface after contraction has taken place is

$$g' = 2 (1 + n) \frac{C T_0 R^0}{R^2} = 2 (1 + n) \frac{C T_0 \rho}{R}. \qquad (22)$$

This value has been multiplied by ρ^{1-n}.

The pressure which the superposed layers are capable of producing is

$$P = \int_R^\infty g'\delta' dR$$

Substituting these values from (21) and (22)

$$P_g = (1+n)(1-n^2)\frac{C^2T_0^2\rho^2}{\pi k}\int_R^\infty \frac{dR}{R^3}$$

$$= (1+n)(1-n^2)\frac{C^2T_0^2R_0^2}{2\pi k R^4},$$

$$= (1+n)(1-n^2)\frac{C^2T_0^2\rho^2}{2\pi k R^2}. \qquad (23)$$

By reference to (20) it will be observed that this pressure is $(1+n)\rho$ times as great as that necessary to hold the gaseous sphere in equilibrium, if no rise of temperature be assumed.

Applied to the initial condition, the equation for a perfect gas is

$$\frac{P_0}{\delta_0} = CT_0.$$

Applied to the final condition after contraction has taken place, the same equation becomes

$$\frac{P_0(1+n)\rho^{2(1-n)}}{\delta_0\rho^{1-n}} = CT_0(1+n)\rho^{1-n} = CT$$

where

$$T = T_0(1+n)\left(\frac{r_0}{r}\right)^{1-n}. \qquad (24)$$

When $n = 0$, in which case the temperature was initially constant throughout the mass, this equation becomes

$$Tr = T_0r_0. \qquad (25)$$

This is Ritter's equation more recently announced by Dr. See.

In the early history of a nebula, the temperature undoubtedly approaches very closely to uniformity throughout the mass. And in the case of the sun, which represents the final stage of a nebula, it seems possible that the same conditions may hold through the greater part of its mass.

In general the temperature throughout a nebula is to be given in terms of the co-ordinates of the point in space where the temperature is to be determined, and the ratio of contraction from any given initial condition.

If the temperature throughout the mass remains constant, Ritter's equation (25), holds during contraction. If on account of unequal permeability to heat the temperature should become unequal, the law of temperature change as a function of ratio of contraction, becomes more complex. If at any time the temperature throughout the mass varies inversely as the n^{th} power of the distance from the center, the ratio of temperature change at any contracting surface is given by (24). It is evident that n cannot be less than zero. This is fixed by physical considerations. If it were less than zero, the temperature would increase from the center outwards.

It is not probable that these equations could represent the general behavior of the nebula throughout its mass, if the temperature departed materially from constancy, as it probably does in the latter stages of condensation. This discussion at least shows that such conditions of temperature, produce effects that should not be ignored.

Another hypothesis in regard to the temperature within and around the sun may be outlined, although the study of the resulting consequences is as yet in an unfinished state.

Let it be assumed that the temperature varies along any solar radius in accordance with the equation

$$\log T = \log B\ (R' - R). \qquad (26)$$

In this equation, R' is the radius of a spherical surface at which the temperature is unity. The temperature at the center is from (26)

$$T_c = B^{R'}. \qquad (27)$$

Eliminating R' in the last two equations

$$T = T_c B^{-R}. \tag{28}$$

There is reason to believe that the solar atmosphere extends 300,000 miles, or 4.828×10^{10} cm. above the solar surface. It has been pointed out that the fineness of the Fraunhofer lines in the spectrum of light originating at the photosphere, makes it exceedingly improbable that a deeper atmosphere can exist. The solar radius is 6.972×10^{10} cm. It will be assumed that at the outer limit of the atmosphere, where $R = R' = 1.180 \times 10^{11}$ cm., the temperature is 1° C. At the solar surface the temperature is at least 5500° C., and is probably more.

According to (26) and (27), by the elimination of B, the temperature at the center of the sun is,

$$\log T_c = \frac{R'}{R' - R} \log T.$$

The numerical values above given being inserted, T_c is found to be 1.338×10^9 degrees C. It is more than likely that at the solar surface there exist condensation effects, in the form of metallic clouds, fogs, and rains. The result will probably be to diminish the temperature gradient somewhat, for points within the sun. The law of temperature probably changes at the solar surface. For such internal points it may in fact be desirable or necessary to assume another logarithmic curve, intersecting the one represented by (26), at the surface of the sun, the constants of which shall be so assumed that the known conditions of mass and surface temperature shall be satisfied. As a preliminary to this study, it seems desirable to learn the results of the assumption involved in (26).

As contraction of the solar nebula has proceeded, the distance R' has diminished, and T_c has increased. Those quantities are to be considered as time functions. In the beginning, as equation (27) shows, the value of B must have been unity.

Substituting the numerical values above given, in equation (27), the common log. of B is found to be at present,

$$\log B = 0.000{,}000{,}000{,}0773.$$

B is also a time function. From the initial condition to the present time, the base B has increased from unity to

$$B = 1.000{,}000{,}000{,}178.$$

If the value of T in (28) be substituted in (3) and this equation be combined with (2) by eliminating δ, the resulting equation may be solved for M. The result is

$$M = -\frac{CT_cR^2}{kPB^R}\,\frac{dP}{dR}. \qquad (29)$$

This equation being differentiated with respect to R, gives

$$\frac{dM}{dR} = -\frac{CT_c}{k}\,\frac{PB^R\dfrac{d}{dR}\left(R^2\dfrac{dP}{dR}\right) - R^2\dfrac{dP}{dR}\,\dfrac{d}{dR}(PB^R).}{P^2\,B^{2R}} \qquad (30)$$

By geometry and by equations (3) and (28),

$$\frac{dM}{dR} = 4\pi R^2\delta = \frac{4\pi R^2PB^R}{CT_c} \qquad (31)$$

Performing the indicated operations in (30) and equating with (31), the differential equation for P, in terms of R is

$$\frac{d^2P}{dR^2} + \left(\frac{2}{R} - \log B\right)\frac{dP}{dR} - \frac{1}{P}\left(\frac{dP}{dR}\right)^2 + \frac{4\pi kP^2B^{2R}}{C^2T_c^{\prime 2}} = 0. \qquad (32)$$

If the primitive of this equation can be found, it may lead to a further comparison of the conditions involved in equation (26) with those known to exist in the sun. The general lines on which such discussion may be made, have been laid down in the present paper, and in the former one to which reference has been made.

Equation (32) may be transformed into one involving a third variable. Thus, the condition that

$$P = \frac{e^{ny}}{B^{2R}}$$

is

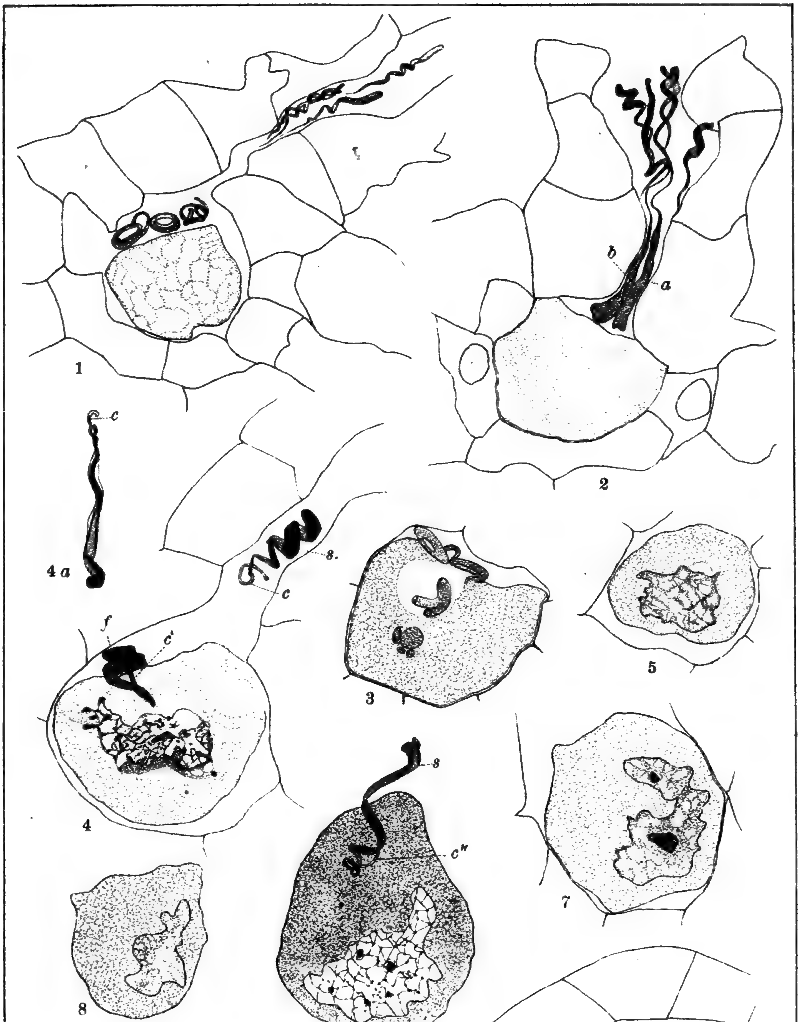
$$\frac{d^2y}{dR^2} + \frac{2}{R}\frac{dy}{dR} + \frac{5}{4}Ae^{\frac{4}{5}y} - \frac{5\log B}{R} + \frac{5}{2}\log^2 B = 0, \quad (33)$$

provided $n = \frac{4}{5}$, and $A = \frac{4\pi k}{C^2 T_c^2}$.

This equation like (32) is not very encouraging in appearance, and it may be that no closed solution can be made of it, or that the solution will be too complex for further application.

Correction. p. 66, line 21 from bottom, for *ten* read *twenty*.

Issued June 14, 1899.



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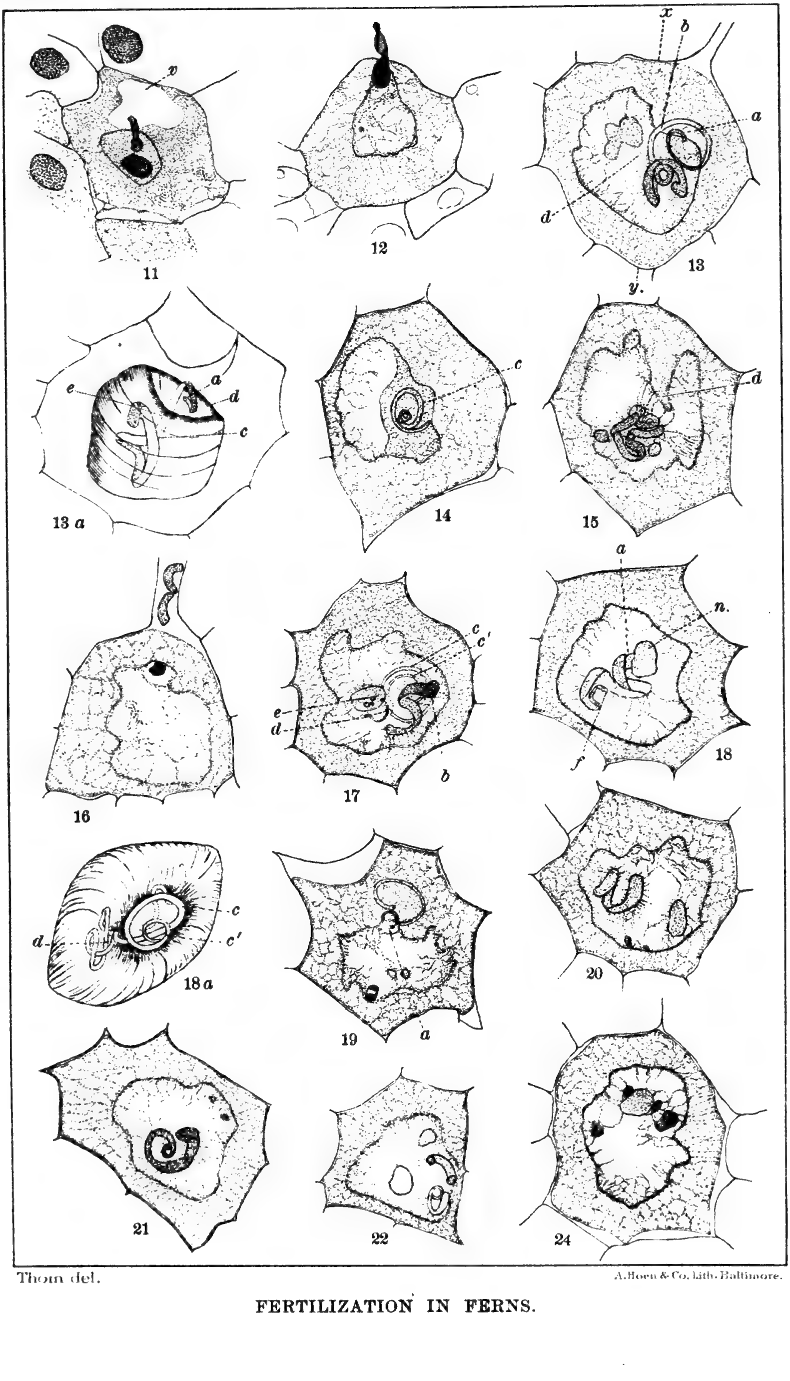
FERTILIZATION IN FERNS.



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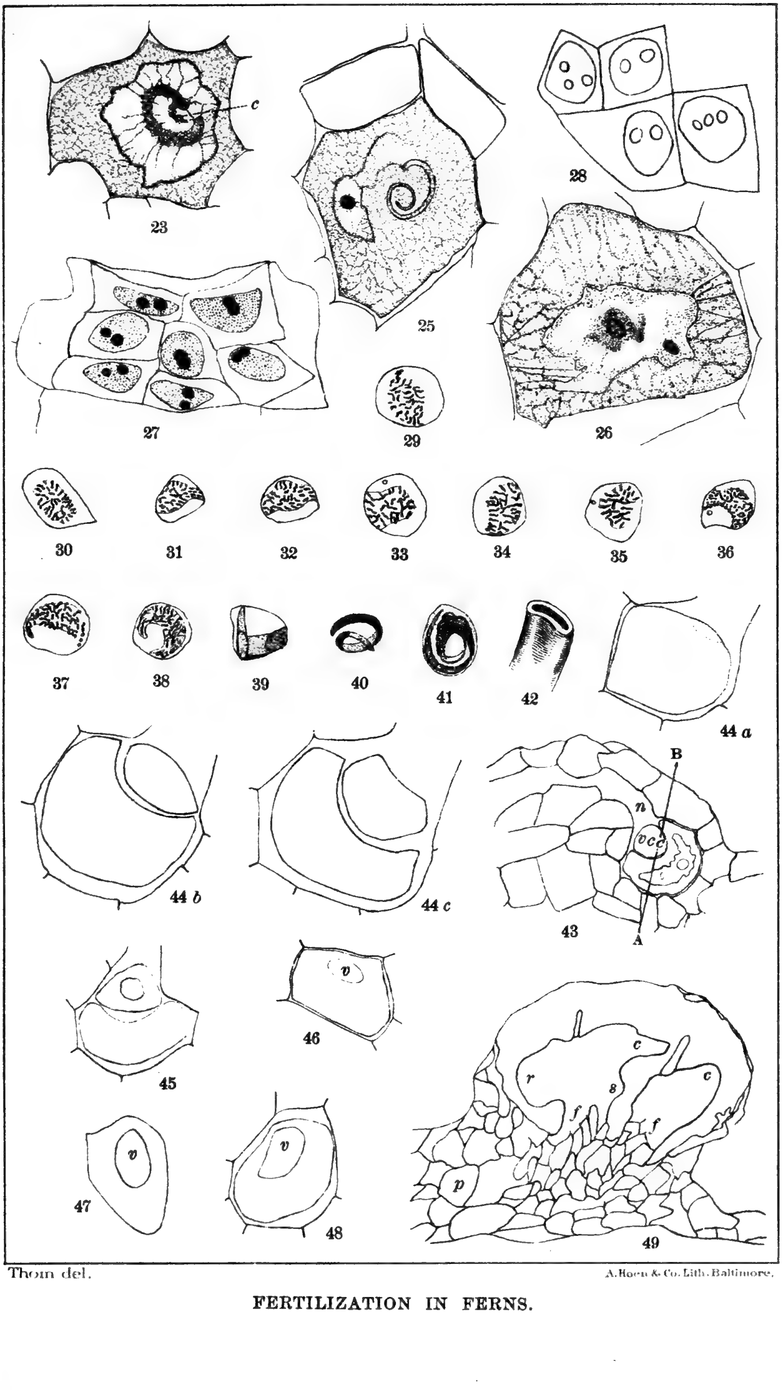

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FERTILIZATION IN FERNS.

THE PROCESS OF FERTILIZATION IN ASPIDIUM AND ADIANTUM.*

CHARLES THOM.

INTRODUCTION.

The investigations of Ikeno, Hirase, Webber, and Shaw have given increased interest and importance to all facts bearing on the process of fertilization in plants. This interest centers on those groups which mark the boundary line between the lower and the higher forms. The correspondence between the results of Ikeno's work on *Cycas revoluta* and those of Shaw on *Onoclea* makes necessary a close study of the details of the fusion of the egg and spermatozoid for related forms. Previous investigations in both animals and plants have shown the spermatozoid as losing its distinct character and assuming the form and appearance of a resting nucleus of equal or nearly equal size with the nucleus of the egg before their final fusion. Ikeno and Shaw, on the contrary, have described the actual entrance of an unchanged spermatozoid nucleus into the nucleus of the egg which is found in the usual resting stage.

The work was begun in the Botanical Laboratory of Lake Forest University under the advice and direction of Dr. R. A. Harper, now of the University of Wisconsin. To him are due the methods of work and much help and advice in the completion of it. The actual study of the material and all of the work on the paper have been done in the Botanical Laboratory of the University of Missouri during the college years '97–'98 and '98–'99. To Dr. Ayers of the University of Missouri I owe the daily assistance and inspiration which has enabled me

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* Presented to The Academy of Science of St. Louis by title, June 5, 1899.— A thesis presented to the Faculty of the University of the State of Missouri for the degree of Ph. D., 1899.

to finish the work since coming here. I am indebted also to Dr. Trelease of St. Louis for material and the use of his excellent library.

MATERIAL AND METHODS.

Fern prothallia may be found very abundantly in any greenhouse where ferns are kept. Most of my material was collected in the greenhouses of Lake Forest and belonged to the genera *Adiantum* and *Aspidium*. Young ferns were grown from part of the material collected and found to be species belonging to these two genera. Since working in Missouri State University I have twice succeeded in collecting material in the field under natural conditions. In both cases the prothallia grew at the mouth of caves and belonged to the species *Woodsia obtusa*. I have also obtained prothallia of the same species from the Missouri Botanical Garden at St. Louis through the kindness of Professor Trelease. I have kept such material in the laboratory under a bell jar where fertilization was accomplished and young ferns were rapidly developed.

To get stages of fertilization in these forms I have found that putting a considerable number of prothallia, removed from the soil as carefully as possible without injury, into a watch-glass and filling it half full of water, gives the best results. They are left in water from an hour and a half to three hours. The shorter time has given the more satisfactory results. The longer times have given figures which seem to be questionable. The archegonia seem to be overstimulated so that cases apparently occur where they open before fully ready for fertilization. Antheridia also seem to burst before the spermatozoids are fully ripe, so that stages where either condition occurs are at least questionable. Killing and fixing has been best accomplished in Flemming's weaker chrom-osmium-acetic mixture allowed to act for thirty to forty-eight hours. The material was then dehydrated and imbedded in paraffin. Shrinkages sometimes occurred, but my figures show that in my best preparations they were extremely slight and in many cases not to be detected at all. The sections were cut five microns in thickness and stained with the Flemming triple-stain safranin, gentian violet, and orange

G, cleared with oil of cloves and mounted in balsam. In my later studies on antheridia, I have fixed whole prothallia by exposure to the fumes of osmic acid. The antheridia were then dissected out with needles under a lens and stained with Haidenhain's iron alum-haematoxylin and mounted in glycerine. The spermatogenous cells could then be easily crushed out. This method, however, gave no better results than the study of antheridia in the sections prepared by the former method, but as a check upon the earlier work the substantial agreement between results was of considerable value.

Study and drawing have been done with a Leitz $\frac{1}{12}$ oil immersion, with a Nachet $\frac{1}{12}$ oil immersion and latterly with the Zeiss Apochromatic 3.00 mm. apert. 1.30, using the Zeiss No. 12 compensation ocular and the new Bausch & Lomb camera lucida — giving a magnification of 1700 diameters.

General Descriptive Notes.

A description of the general morphology of the archegonium and antheridium in the group would be superfluous. A few observations upon the special distribution of organs on prothallia may be of value. Prothallia bearing antheridia only were often found in both forms, but such prothallia rarely showed that typical heart-shape which is universally described for this group of ferns. Their outline was usually irregular, rarely showing the notched apex at all. In ordinary monoecious forms antheridia are developed much earlier than archegonia, and are freely distributed over about one-third of the surface. This area extends from the base of the notch backward. Antheridia are rarely found farther forward than the base of the notch or closer to the edge than one-third of the diameter of the prothallium. I have only once observed an antheridium developed upon the upper surface. Neither antheridia nor archegonia depart from the well-known descriptions in general structure or development. The archegonia in these forms are distributed only on a comparatively small space ranging directly backward from the notch. On older prothallia, if no embryo is developed, the area devoted to the development of archegonia becomes sometimes quite large, so that often a considerable number become ripe at once. In one case I found spermatozoids attracted toward and actually entering six archegonia. There is usually but one or at most two fully developed archegonia at any one time except in these older and larger forms. I have sectioned some hundreds of prothallia and found but one case where an archegonium was developed on the upper side. The case occurred where the prothallium producing it was overlaid by another so that its presence was due to the conditions of moisture and nourishment induced by the second prothallium, agreeing with the result of experiment where such archegonia were artificially induced by Heinricher.

If, however, we turn to *Woodsia obtusa* and consider the prothallium in that fern for comparison, we do not find the regularity in shape and form so distinctive of the others. The prothallia here tend to grow in length with approximately a regular width. The sides are sinuate so that such prothallia do not usually lie flat upon the substratum. Here as in the others the margin of the prothallium is but one cell-layer in thickness, but instead of a gradual thickening we find a definite thickened ridge developed on the under side upon which antheridia and archegonia are produced. The production of sex organs begins somewhat earlier in this form, and continues in the newer portion of the gradually lengthening prothallium until a fertilization is accomplished.

In contrast to the observations of Jeffrey on *Botrychium*, I found but one case among the large number examined where two archegonia upon the same prothallium had been fertilized, and produced embryos. In this case (fig. 49) the two embryos formed lie so close together as to indicate a possibility of the ultimate fusion of the two had their development been continued. This observation is of interest on account of its bearing upon the views of polyspermy in ferns, advanced by Lowe ('95) in his "Fern Growing," where he finds on different portions of the same plant the characters of as many as three or even *six* (!) different species. He has not attempted to determine by histological methods whether this remarkable phenomenon results from the fertilization of three or more separate oospheres by spermatozoids of as many different species, and a later fusion of the embryos into a sort of "*composite plant*," or a true case of polyspermy. The presence of a number of spermatozoids in the neck of the archegonium or even in or upon the egg itself is common, and has been many times described. But there does not seem to be any positive evidence that more than one spermatozoid actually unites with the egg — or should such cases occur, that the embryos so formed would develop into ferns. Lowe accepts the theory of polyspermy, but bearing in mind that the fertilized egg is a single *cell*, and as such should act as a unit, the resulting hybrid, if it reached maturity at all, would be expected to show uniform characters. It is, however, entirely possible that two such embryos as shown in figure 49 could fuse to produce a single stem so that their individuality would be, apparently at least, lost. In fact the very closeness of the archegonia to each other would make such a result easily possible and rather difficult to avoid without the crowding and dwarfing of both or the actual destruction of one.

THE SPERMATOZOID.

Before attempting to discuss the process of fertilization we must first consider the gametes separately. Belajeff ('97) gives the following as general for the *Filicineae:* "Das reife völlig entwickelte Spermatozoid besteht in seinem hinteren Theile aus einem ziemlich dicken spiralformigen Chromatinkörper der von einer dünnen Plasmahülle umgeben ist." — "Das vordere Ende des Spermatozoidenkörpers hat eine bandartige Form, reagirt wie Plasma und scheint gewissermassen eine Fortsetzung der Plasmahülle des Kernes darzustellen." He also notes that it carries with it a cytoplasmic vesicle or remnant at its posterior end. In my preparations the ripe spermatozoid consists (figs. 4, 4a) of a large nuclear portion tapering from a blunt end behind to a slender but not sharp point forwards and thrown into from two to three turns of a spiral. The number of turns depends to a large extent upon whether the spermatozoid is in motion or at rest, free or crowded together with others into the neck of the archegonium. At the pointed end of the nuclear portion I could determine by careful staining about one and a half short turns of the spiral which contain no chromatin and must be regarded as cytoplasm. At the end of this cytoplasmic portion an enlargement may sometimes be demonstrated (fig. 4) at or near which the cilia seem to be attached. I have not been able to stain them to show their actual points of attachment. At the time of fertilization I have not been able to distinguish any cytoplasmic vesicle attached to the blunt end of the nucleus, although Belajeff describes it as present. Shaw describes it as actually torn from the moving spermatozoid as it becomes entangled in the slime at the mouth of the archegonium. I have observed it in the free swimming spermatozoid. The nuclear portion is enveloped by a cytoplasmic covering (Hülle of Belajeff) which appears to be continuous with the forward coils which bear the cilia. This envelope or covering has been variously described. Guignard claimed that the entire body of the spermatozoid except the cilia and the vesicle behind was nuclear. Of this the forward coil bearing the cilia showed no chromatin though it was continuous with the chromatin-bearing portion. Belajeff finds the anterior end a cytoplasmic band inclosing a deeply staining fiber or thread derived from the "Nebenkern," curving around the nuclear portion and, presumably, inclosed in the same cytoplasmic covering (Hülle) as the nucleus. Schottländer described in addition to the same cytoplasmic envelope a band or "Segel" the whole length of the nuclear portion. I have seen a similar appearance at times, but on the basis of my observations of the living spermatozoid and the fate of its several parts in the fertilization process, I am convinced that the cytoplasmic envelope does not fit the nucleus closely. The nucleus lies in one side, so that the appearance of a band may be due to the collapse or partial collapse of the portion not distended by the nucleus. This explanation would correspond more nearly with the observation of Shaw for *Marsilia* where he finds a thread derived from the "blepharoplast" not only in the forward coils but traversing the full length of the nuclear portion and even extending out behind it. It also agrees with the statement of Belajeff that the thread derived from the "Nebenkern" lies in one edge of the cytoplasmic band which constitutes the forward end, while the pointed end of the nucleus appears on the opposite edge of the band in the third turn of the spiral.

In considering the function of the spermatozoid and its various parts, it is necessary to go back and review to some extent at least its development. The antheridium contains a number of "spermatozoid mother cells" ("spermatogenous cells" or spermatids, if we are to use the same term as the zoologist), varying from 32 to probably 128. The prothallia differ in the number produced, and often antheridia on the same prothallium seem to contain different numbers. The number probably varies inside these limits, however. Belajeff observes that the spermatogenous cell contains a large nucleus which comes to lie upon one side of the cell (fig. 28) close under the wall. At this time, according to his statement which he makes general for the *Filicineae*, there appears in the cytoplasm a round granule or body staining more deeply than ordinary cytoplasm and sharply marked off from it. He describes this body under the name of "Nebenkern." Shaw observes and describes the same body under the name of "blepharoplast" and finds it present in the mother cells of the spermatids in *Marsilia* and *Onoclea*. That is, according to Shaw, the blepharoplast in these forms must divide with the division of the cells at least once before it assumes its final form. This is unquestionably the same body which was described by Webber for *Zamia* as "blepharoplast" and has since been decribed by Ikeno for *Cycas* as a centrosome. In my material, at a stage just preceding this, the nucleus contains a network bearing large chromatin granules which are disposed, for the most part at least, close under the nuclear membrane. There are from one to three large nucleoli which stain a clear red with safranin while the chromatin takes a deep blue from the gentian violet (fig. 27). Comparing this figure, where changes have already begun, with earlier stages, there seems to be a rapid increase in nucleolar material. In many cases the nucleoli appear to have just divided. All of the cells of the antheridium appear to be in nearly the same stage, and there is a great regularity in the successive changes as they occur in cells of the same group. This regularity is so marked and so extensive at times that all the spermatids of an antheridium are not only in the same stage of development at one time, but often appear to develop spermatozoids which are oriented in the same way in the cell.

I find the so-called "blepharoplast," or "Nebenkern," as a round body lying outside the nucleus toward the center of the cell, usually. It stains as the nucleoli within the nuclei did before its appearance. Sometimes it is connected by strands or fibers with the nucleus — more often such connection could not be demonstrated. The body, however, seems to be present in all cases. It is noticeable that the nucleoli, as distinct bodies, disappear *before* the appearance of this body. At least I have not observed both as present at the same time. This disappearance of the nucleoli at the time of the appearance of the blepharoplast would suggest a relationship between them, in material at least. They stain alike. The blepharoplast when first seen occupies a position which, to say the least, could easily have been occupied by one of the nucleoli before the nucleus left its position at the center of the cell for the secondary position near the wall. Further, the nuclear membrane, if it remains intact, has become so thin that it is difficult to follow. Although I have not observed its origin from the nucleoli, such a theory goes farthest toward explaining the changes which occur. Such a theory, coupled with the fact that it contains kinoplasm, as shown by its function as a bearer of cilia, would agree with the conclusions of Strasburger ('97) as to the kinoplasmic nature of the nucleolus.

I cannot confirm the observations of Belajeff, Ikeno, and Shaw, that the first step in the development of the spermatozoid is the stretching (Ausdehnung) of this body first into a crescent, then gradually into a fiber which forms a dark line on the edge of the cytoplasmic anterior end of the spermatozoid. I have observed it many times unchanged when the nuclear portion of the spermatozoid had developed into a whole spiral turn, and sometimes even more. Many of the later stages of spermatogenesis and adult figures, as figure 4, indicate that this body comes to lie at the tip of the cytoplasmic end of the spermatozoid. The nature of the body is still questionable. It has been shown by Belajeff for the *Equisetaceae* to be the origin of the cilia. Webber, Ikeno and Shaw find the same to be true. This function points toward a relationship with the centrosome in lower plants as described by Strasburger or in animals as has many times been shown. But beyond serving as the origin or point of attachment of the cilia it develops no function. It does not act as a centrosome in nuclear division (see Ikeno's own figures), and is lost before fertilization, so fails to perform the two chief functions of a centrosome. Guignard, investigating the spermatogenesis of *Chara*, found the earliest change was the formation of a darkly staining line just inside (possibly outside) the nucleus which develops into the head end of the spermatozoid and contains little or no chromatin. His description, although he regarded the body as inside the nucleus, corresponds to a large extent with the recent observations of the development of the blepharoplast. In my own material no such change appears at first. I have not been able to determine exactly when the cytoplasmic forward or head end is formed, but certainly the earliest change involves only the nucleus.

Our chief interest, however, lies in the transformations which occur in the nucleus. In figure 27 we see the notable changes taking place. The nuclei have become elliptical and in some cases pointed at one end. The chromatin appears in the form of granules deeply stained (blue) on a network of achromatic material or linin. This network is massed near the surface of the nucleus. The prominent nucleoli (stained red) occupy a more central position. Two of them appear in each cell, but in figure 28 part of the cells contain three instead of two, so that although the position of the nucleoli with reference to each other indicates multiplication by division, the number present is not essential. The nucleus now lying very near one side of the cell becomes flattened tangentially into a band lying just under the wall with its concave depression toward the center of the cell. In this concavity we find the blepharoplast (figs. 29, 36). The flattening process is accompanied by the elongation of the nuclear body into a pointed and a blunt end (figs. 29–37), with an enlargement at its center. This development into a pointed end may be abrupt as in figure 31, where it is seen from above, or appear as gradual (figs. 27, 37, 38). Of these two ends the more pointed is usually the longer. The chromatin material is now seen in short thick masses or bars lying on the surface; the achromatic material cannot be distinguished clearly. The bars of chromatin begin to connect together into a network. The nucleoli are no longer to be seen, but there appears to be a red-staining ground-work or central mass to the whole nucleus. The bars of blue-staining chromatin stand out sharply on the surface of this red-staining central mass. The further changes in the nucleus are a thickening and connecting together of these chromatin bars, the lengthening and continued flattening of the body. In figure 41 the anterior end of the nucleus appears to taper gradually towards a blunt point; the posterior end is spread out into strands. In this figure the cytoplasmic anterior end has become nearly one-fourth of the turn while the nuclear portion has reached about one and a half spiral turns. The chromatin is connected together into strands with a tendency to longitudinal arrangement, with crossing bars of the same material. Within this network of chromatin there is a distinctly red-staining mass. Similar proportions have been developed in figure 40.

As the spermatozoid ripens, the chromatin mass is transformed into a dense layer over the surface of the now band-like nucleus, which explains Belajeff's observation that it is a homogeneous chromatin mass. If, however, we examine the cross-section, as he does not appear to have done, we get further evidence. In figure 42 we have a drawing of an actual cross-section of a spermatozoid lying in an archegonium upon an egg-cell magnified 2550 diameters. The chromatin here appears as a deep blue layer on the outside of a red central body. The nuclear body here is seen to be flattened, concave on the inner side of the coil, convex on the outer side, and perhaps a little thicker at the edges than in the center. The nuclear portion of the spermatozoid is about forty microns in length, perhaps three microns in greatest diameter. If it were a solid mass of chromatin, it would require much more such material than we find in the nucleus of the spermatid, which is scarcely six microns in diameter. Schottländer in his observations on the spermatozoid of *Aneura pinguis* finds a similar ground substance in the center of the nuclear portion surrounded by a chromatin layer. Zacharias ('87) in investigating the spermatozoids of *Chara* has shown by micro-chemical means that the ciliate anterior end and vesicle behind are cytoplasmic. By digestion experiments he succeeded in dissolving the chromatin, leaving the anterior end and the cytoplasmic posterior end connected by the cytoplasmic envelope and a delicate fiber (zarte Faden) in the center whose nature remained undetermined. By digesting the nuclear portion Strasburger demonstrated the cytoplasmic envelope of the nucleus but does not mention a central filament. Belajeff by a similar experiment found the two ends connected by a slender thread, which may have been either this central filament or the cytoplasmic layer on the outside. These tests show that the cytoplasmic forward end and the connecting fiber react in the same way as the kinoplasm of the spindle fibers, which would fix them as kinoplasmic structures. The same central filament is described by Franze ('93) as "Achsenfaden." On the basis of my own observations it seems to be nuclear in origin and probably represents some transformation of the large amount of nucleolar material present in the earlier stages.

To recapitulate the structure of the spermatozoid of the fern as now understood: — The entire body forms a left-handed screw or spiral about forty microns in length and possibly three microns in greatest diameter. The anterior cytoplasmic portion forms about two spiral turns inclosing a body or thread derived from the "Nebenkern" or "blepharoplast" which bears the cilia. The central portion of the two much larger and longer coils consists of the nucleus and its cytoplasmic envelope. The diameter of the nucleus increases from a pointed end in front to a blunt end behind. The posterior portion is a cytoplasmic vesicle attached to the inside of the last coil of the nucleus. The cilia, according to Belajeff, exceed forty in number. They are, for the most part, at least, directed backward and exceed in length the body of the spermatozoid, instead of being comparatively short and directed outward as they have previously been described and figured. Their motion passes backward in waves from their origin at the anterior end of the body toward their free ends, so that as much as two waves of motion can sometimes be seen at once following the curves of the body of the spermatozoid backward. The cytoplasmic coils and at least the first turn of the nucleus seem to be actively motile also, so that in addition to the whirling motion imparted by the cilia the spermatozoid undergoes a rapid succession of changes of form. I have not determined just how much power of movement may be attributed to the nucleus itself, but the fact that the nuclear portion of the spermatozoid enters the egg without assistance from the cytoplasm proves that it has that power in some considerable degree at least.

THE EGG-CELL.

The egg-cell lies in the venter of the archegonium closely invested by the richly nourished cells lining the cavity in which it lies. It varies in diameter from about twenty-five microns to forty microns according to the direction in which it is measured. Its form in different archegonia varies from nearly spherical almost to lens-shaped. The ventral canal-cell lies in a concavity of its upper outer surface but usually not in the center and often very nearly at one side. The diagram (fig. 43) is a part of a vertical longitudinal section of a prothallium through the neck of the archegonium and the middle of the egg-cell. Here it is readily seen that the ventral canal-cell (v. c. c.) lies at the bottom of the open neck of the archegonium (N) but that this point lies at one side of the center of the oosphere or egg. The egg extends outward beyond the ventral canal-cell, so that it has come to lie in the side of the egg and to be surrounded by it except on the side turned toward the open neck. Now a section cut in a plane parallel with the line A-B and perpendicular to the plane of the section in figure 43 will explain such appearances as the open cavity *v* which appears in figures 10 and 11 and in the diagrams 46, 47 and 48, which are camera outlines of sections of egg-cells. The opening *v* is then only the cross-section of the cavity which the ventral canal-cell occupied at an earlier stage as figure 43. In figure 44a the edge of the cavity is indicated by the dotted curved line as lying below the plane of the section; in 44b and 44c, which are succeeding sections of the same egg, it becomes very prominent. If the cell were followed through, the same appearance as 44a would be reached on the other side, or if a median section perpendicular to the plane of 44c were taken the figure would be nearly the same as 44c. Such openings surrounded by egg-cytoplasm can easily be mistaken for a "receptive spot" developed in the egg itself when they are really outside the cell. This concavity is not uniform in its development, nor when present does it always show as in the diagrams. It lies at the bottom of the neck of the archegonium. The position of the neck of the archegonium varies from almost perpendicular to the surface of the prothallium (fig. 2) when the ventral canal cell lies near the center of the egg, to an angle of less than forty-five degrees (figs. 1, 9 and 43) when the cavity usually lies far to one side. The egg-cell adapts its form to the shape of the cavity in which it lies. This concavity in its surface is not always present. In the egg shown in figures 6, 7 and 8 there was no such spot in any section. Instead we find a decided convexity of surface while the spermatozoid (*s*) is seen entering the cytoplasm a little to one side of its pointed end. This seems to be but another evidence of the amoeboid character of the egg. Shaw describes such figures as this, as a change from a concave surface to a convex surface occurring in the living cell as soon as the pressure of the ventral canal-cell is removed. He suggests that it is a readjustment due to turgidity of the egg and states that it returns to its former shape as soon as the spermatozoid has entered. Such a change from a concave surface to a convex surface probably did occur in the egg shown in figure 6, but it cannot be a constant phenomenon, for I have observed it only once or twice in the large number of archegonia examined. Further I see no evidence of any return to the former shape either in figure 6 or in any other sections examined, so that I doubt if such a change occurs in these forms in any case.

The nucleus of the egg in its early stages shows the ordinary spherical form with one or two large nucleoli and abundant sharply stained chromatin. As the egg nears maturity, the chromatin becomes indistinct with the ordinary stain, the regular contour of the nucleus disappears, and the only prominent feature remaining is the large nucleolus. The nucleolus itself shows commonly an irregular form and appears vacuolated. Careful staining and examination enables one still to see a nuclear network upon which fine granules are distributed. These granules stain blue with gentian violet. This distinct staining reaction and the marked difference between these and the cytoplasmic granules outside justify the claim that this material is chromatin, which is only in a very finely divided state. Such networks can be seen in figures 4, 5, 6, 7 and 8, where the necessity of distinguishing chromatin from cytoplasm by a difference in shade in the drawing has made the nuclear network more prominent than it really appears in the microscope. The difficulty of showing the presence of chromatin in the unfertilized egg led Zacharias, in 1887, to say that no chromatin framework had been demonstrated in the egg of *Pteris serrulata*, *Marchantia polymorpha*, *Pinus sylvestris*, *Thujopsis dolobrata*, *Lilium candidum*, *Monotropa hypopitys*, or among animals in *Unio* or *Rana*. The same difficulty has recently been noted by Gardiner in *Polychaerus caudatus*. Chromatin is easily stainable in the last division spindle in the formation of any one of these eggs. It may be readily demonstrated in the younger stages of the egg itself, but in the ripe egg Zacharias could find no satisfactory micro-chemical evidence of its presence at the time of fertilization, although a plastic framework could be found. These observations seem to show that at the time just preceding fertilization the egg chromatin differs so greatly in its distribution at least, if there is no change in its chemical character, that it fails to give the ordinary reactions which so easily demonstrate its presence before and after this period. During the entire time the nucleoli maintain their size and position unchanged.

The whole nucleus now seems to be irregularly crescent-shaped, with its concavity parallel with the concave depression in the outside of the cell (figs. 6, 7, 8, 10, 14, 25). Careful tracing of the nuclear membrane shows it still sharp, but thin and thrown into folds like pseudopodia. The difference in staining reaction between the nuclear material and cytoplasm makes it possible to follow the delicate pseudopod-like branches of the nucleus through the cytoplasm. Such a branching condition of the nucleus rendered adequate representation of it in drawings unsatisfactory, so finally the plan adopted was to fix upon some point in the section, sometimes the upper cut surface, sometimes what I determined was the optical section, again some point which was important, and draw the outline of the nucleus in that plane. Within such figures I have represented the spermatozoids as they enter, as nearly as possible in perspective maintaining their true relation to the plane of the figure. Sometimes it was necessary to represent by a change of shade more than one plane of the egg (figs. 13, 17, 25) because a portion of the spermatozoid lay in the cytoplasm outside the nucleus but was partially overlaid by it in the plane of the figure. At its maturity, then, the egg contains a large amount of cytoplasm which appears as a granular network staining evenly for the most part, yet showing in places larger granules or microsomes whose nature has not been determined. The cytoplasmic network often shows an irregularly radial arrangement into fibers and rows of granules directed outward from the nucleus. The shape of this mass of cytoplasm is determined by the cavity in which it lies. Within it is the irregularly branching nucleus which usually occupies the center of the cell body. It approaches nearest to the surface, however, at the base of the depression which is filled in the earlier stages by the ventral canal-cell. This is the point where fertilization occurs, for here the entrance of the spermatozoid nucleus into the egg nucleus is most easily accomplished.

FERTILIZATION.

The actual fusion of the two nuclei has been observed in only a few plants. In 1869 Strasburger observed the entrance of the spermatozoid into the archegonium of *Pteris serrulata* and in *Ceratopteris*. He saw it disappear within the egg itself and observed the formation of a membrane around the fertilized egg within a very few minutes afterward. The entire process required a very few minutes, but the actual relations of the nuclei were scarcely touched. A fusion of the two nuclei in the resting stage has been described by Wager and Harper in fungi, by Oltmanns in *Vaucheria*, by Farmer and Williams in *Fucus*. Campbell has described changes in the spermatozoid of *Pilularia* before its fusion with the egg nucleus which point to a similar occurrence in that form. Ikeno has figured the entrance of the spermatozoid nucleus unchanged into the egg nucleus in *Cycas*. Shaw has made the same observation in *Onoclea*.

The entrance of spermatozoids into the archegonium can be easily observed under the microscope. I have not, however, attempted to control it in many cases. By removing prothallia from the soil and flooding considerable numbers in a dish together, I believe that I get the nearest approach to normal conditions. In this way I have secured a fairly representative series of stages.

After treating them as described above, the mouth of the archegonium will generally be found to contain a number of spermatozoids varying commonly from one or two to twenty or more. When the number is large they are usually so wound together that it would be hopeless to attempt to trace out the relations of each (figs. 1 and 2). Shaw has observed the spermatozoids "swimming into the archegonium, swarming over the egg and escaping again," yet he notes that as they become entangled in the slime at the mouth of the archegonium their progress is impeded and the cytoplasmic vesicle torn off. I have found that spermatozoids are attracted toward and enter archegonia which have degenerated. They may be found piled upon egg cells which have passed the stage of maturity and lost the capacity for fertilization. In such cases the amount of slime at the mouth of the archegonium would not prevent the free entrance and exit of spermatozoids. From my own observations I doubt if a spermatozoid, after once entering the neck of an archegonium which is ripe for fertilization, escapes again, or even endeavors to escape.

Entrance into the neck of the archegonium is always effected with the pointed or cytoplasmic end forward. In entering they become usually drawn out into more, but shorter, turns. Figure 2 represents a striking condition. In this figure the two prominent spermatozoids, *a* and *b*, are directed into the archegonium *large end* first, while their pointed ends are entangled with those which lie in the outer portion of the neck. These might appear to be cases where the spermatozoids once in are endeavoring to escape. But a comparison with the spermatozoid in the neck of the archegonium in figure 4 and with figure 4a, where the spermatozoid lay just outside the mouth of the archegonium, suggests a different explanation. In figure 4a the cytoplasmic portion *c* is already disconnected and turned backward. In figure 4 the cytoplasmic end *c* of the spermatozoid *s*, though not broken off, is turned backward as if useless. A similar portion *c′* of the spermatozoid *f* seen entering the egg seems to be dragged into the cytoplasm backward. The same has also occurred apparently in *c″*, figure 6. Such figures, combined with the fertilization figures 9, 10, 11, 12, lead to the conclusion that as soon as the spermatozoid has entered the mouth of the archegonium the function of the anterior end is completed; consequently when it appears in any later stage it is merely passively dragged along. The fact that this portion is at times broken off, at times turned backward, and, as Ikeno has shown, entirely dropped before fusion, indicates that it contains nothing essential for fertilization. It contains the blepharoplast. This would prove that the blepharoplast is not essential to fertilization in the sense in which a centrosome is given that character, but a special organ differentiated for the production of cilia. In figure 2 the aggregation of the chromatin toward the ends of *a* and *b* which are inside the venter of the archegonium, compared with figures 9, 10, 11 and 12, is good evidence that each spermatozoid is endeavoring to get its entire body inside the archegonium not to escape. Combine this with the separation of the cytoplasmic end in figure 4a and its marked loss of function in *s*, figure 4, and we have sufficient grounds for saying that the attractive impulse which leads finally to fertilization must be exerted directly upon the nuclear portion of the spermatozoid. This portion, as seen in figures 2 and 4 and also in the fertilization figures 10, 11 and 12, must have the same power to respond by motion toward the egg when it lies outside that it undoubtedly has after it is inside the egg cytoplasm. In the fertilization of the animal egg (Wilson, 1896; Wheeler, 1896) the tail of the spermatozoid furnishes the motive power until the nucleus enters the cytoplasm of the egg. The tail is left outside, or if carried in is functionless. The nuclear portion often traverses many times its own diameter before fusion with the nucleus of the egg. In the fern we have a spiral nucleus in the spermatozoid, at least one turn of which is actively motile. In either case the directive influence must be exerted on the nucleus. The only difference then is that in the fern we are describing, its influence is exerted upon the nucleus alone and responded to a little earlier. The cytoplasmic portion may be dropped or become functionless as a locomotive organ before the gametes are in actual contact without interrupting or interfering with their ultimate fusion.

One or more spermatozoids finally come to lie in the depression in the upper surface of the egg (figs. 3, 4, 10) where they may be often seen coiled in the sections examined. Others may be found in almost any position upon the surface of the egg cell (figs. 1, 3). One spermatozoid now bores or forces its way into the cytoplasm of the egg (figs. 4, 6) toward the nucleus. In figure 6 there is no depression in the surface and we find the spermatozoid entering the cytoplasm near the tip of the egg. In figure 4 the depression is not clearly marked as in figure 3, but there is a marked flattening and slight concavity of surface. In both of these cases the pointed forward end penetrates first. Although not so marked in these figures as in figures 10, 11 and 12, the spermatozoid usually breaks in toward the center of the concavity of the nucleus, which usually lies closest to the surface at the base of the depression in the surface of the cell.

In figure 10 we see a portion of the spermatozoid *f* coiled in the depression in the surface of the egg which appears in the section as a hole in the egg-cytoplasm opening to the outside beneath the plane of the section. Here a *blunt end* of the spermatozoid is seen extending through the cytoplasm, interrupting or breaking the nuclear membrane and actually entering the nucleus itself. The contour of the nucleus is drawn at the plane where the nuclear membrane is interrupted for the entrance of the spermatozoid. The appearance of this nucleus is fairly typical for a vertical longitudinal section at this stage. If the section were above the plane of this section, the nucleus would show a contour much more nearly round. We have here a figure where the nuclear portion of the spermatozoid lies partly *inside the nucleus of the egg, a part extends through the cytoplasm* and a portion still lies coiled in a depression in the surface of but *entirely outside the egg.* That is, the actual process of the union of the two gametes is before us.

In figure 11 we have a similar condition. The nucleus in this section lies very close to the surface of the cell — the bottom of the depression in its surface *v*. Only a small portion of the spermatozoid remains in this case — the larger part was carried away by the knife and will be found in the next section. Here again the portion present lies partly inside and partly outside the egg nucleus and it enters blunt end first. In figure 12 the egg cell had no depression in its upper surface. The spermatozoid has broken through the very tip of the cell. The part present shows the distinctly spiral appearance of the spermatozoid and is certainly entering large end first.

We get a more striking condition in figure 13 than in any of the others. Here one large coil and a half smaller, *a*, are seen lying outside the point *b* where the spermatozoid breaks through the nuclear membrane. The entire nuclear portion (stained deeply) lies inside the egg nucleus but is connected distinctly or rather is continuous with the coils lying outside the nucleus. In this figure the egg nucleus is drawn in the plane where the spermatozoid breaks through the nuclear membrane. The lightly colored coils of the spermatozoid contain no nuclear material. The part from *a* to *b* lies in the concave depression of the nucleus which is just below the plane of the section, as is indicated by the dotted line *d*, which is intended to show that the cytoplasm at that point is but slightly below the plane of the section. A comparison of this with *s*, figure 4, and with figure 4a shows at once that the portion appearing now as non-nuclear, and in this case connected directly with the nuclear portion, is several times greater than the cytoplasmic forward end of the free swimming spermatozoid. But one interpretation seems to be admissible — that when the nuclear portion has forced an entrance into the egg-nucleus it breaks out of its cytoplasmic envelope and slips into the nucleus of the egg, leaving the empty envelope behind in the cytoplasm. This agrees with the statement of Ikeno for *Cycas* — "Sofort nach seinem Eindringen in die Eizelle schlüpft das Spermatozoid aus seinem Cytoplasmamantel, welcher sich bald innerhalb der Eizelle desorganisirt, während gleichzeitig der Spermakern nach dem Eikerne sich hinbewegt" (p. 595). In the fern, however, the cytoplasmic mantle, having the spiral form of the spermatozoid, can be more easily identified, to the last. It contains less cytoplasm than that of *Cycas*, consequently fits the nuclear portion more closely, so that it is carried further into the egg, while in *Cycas* it is left (Ikeno, fig. 35) at the periphery of the egg. Here it is carried as far as the nuclear membrane ordinarily, and in this one case I find it was drawn partly inside before the nucleus finally escaped. Figure 13a represents in a somewhat diagrammatic way the same nucleus as figure 13, leaving out details in shape, and turned on a vertical axis as *x-y* about ninety degrees. In this figure the funnel-like depression *d* lies in the upper surface a little on one side of the center. Its edge is much higher on one side than on the other. In fact this depression, to which the name "receptive spot" has often been applied, is no more regular in shape and position than the outline of the nucleus. Its occurrence is due to the fact that the nucleus conforms itself in a general way to the shape of the cell. The depression occurs in the surface of the cell, and the nucleus, having the peculiar amoeboid form, naturally shows the same depression. The spermatozoid coiled in this receptive spot broke through the nuclear membrane at the point *e* just about the lowest point in the funnel *b*. Outside the nucleus we find a coil and a half beginning at *a* and passing through the nuclear membrane at *e*. This part contains no nuclear material and continues without chromatin through the nuclear membrane as far inside the nucleus as *c*, where it passes under a turn of the nucleus. That is, the part from *a* to *c* contains no nucleus. Passing under the coil of the nucleus at *c*, it reappears on the other side as nuclear. The connection between the two could not be seen, but the fact that they were connected is beyond question. A glance at the part from *a* to *c* and a comparison with the nuclear portion show that the two are almost of equal length and similar in diameter. So we have here in the same figure both nucleus and its cytoplasmic envelope and both perfectly recognizable.

Figures 17 and 18 are two sections of another egg in the process of fertilization. In this egg the depression lay in the side of the cell in the section below the one shown in figure 17. Figure 18a is intended to show the nucleus of this egg viewed from the mouth of the archegonium, leaving out entirely the details of form. The nucleus is very large, quite irregular in outline, with a marked depression in the side, turned toward the mouth of the archegonium. The colorless coils *c*, *c′*, of the spermatozoid lie in this depression just below the plane of the section in figure 17, viewed from above in figure 18a. The point *d*, figure 18a, shows the end of the nuclear portion of the spermatozoid just inside the nucleus of the egg still connecting with the colorless portion outside the nucleus. The point of entrance lies behind the nucleolus *e* in figure 17. Once inside, the entire sperm-nucleus may be followed through the two sections. It was reconstructed in wire and drawn to scale in figure 18a. Careful examination of the end *d* in figure 17, which is continued in the portion *f* of figure 18, shows that in this case the slender pointed end was the last to enter the nucleus of the egg. The same fact is indicated in figures 10, 11 and 13, but is best demonstrated in this figure where both blunt and pointed ends may be found in the same section. This spermatozoid seems therefore to have coiled itself in the depression in the surface of the cell. It then broke through the cytoplasm into the egg nucleus and slipped out of its cytoplasmic envelope, large end first, directly into the nucleus. The colorless coils *c*, *c*,′ are the cytoplasmic envelope and lie entirely outside the nucleus. The pointed end *d* of the sperm-nucleus has just escaped from the cytoplasmic envelope. The fact that in this case at least the entrance of the spermatozoid is effected large end first is another evidence that the attraction which leads to entrance is exerted between the nuclei. There certainly is not a complete differentiation into an anterior and a posterior end at this stage. These observations confirm the statement that the prominent spermatozoids in figure 2 are entering large end first — that is, that the sperm-*nucleus* responds directly to the stimulus which draws it into the egg.

After the sperm-nucleus has entered the egg-nucleus, the fertilized nucleus shows a distinct tendency to develop a smooth contour. The irregularity in the shape of the nucleus begins to disappear. The changes which take place in the sperm-nucleus are exceedingly difficult to represent in detail. Connection is made almost immediately with the nuclear network of the egg. The surface of the sperm-nucleus begins to appear granular as if the whole chromatin surface were breaking up again into the separate granules of which it is composed. This process does not follow in reverse order the process of development, but the granules when first seen are very fine and small like those of the egg chromatin.

Figures 14, 15 and 16 are from successive sections of another egg-cell where the spermatozoid has already entered the nucleus leaving its cytoplasmic covering, *c*, figure 14, outside the nucleus. These coils lie below the plane of the drawing in figure 14 in the depression of the nuclear surface which is shown so strikingly at *d*, figure 15. In figure 14 this funnel-like depression lies below the plane of the figure and is overlaid by the nucleus. Its funnel-like character is shown in figure 15, where it comes more nearly to a point than in any other case observed. A comparison with figure 14 shows, however, that it lies in the side of the nucleus and opens on one whole side instead of only at the mouth of the funnel. The sperm-nucleus here shows considerable progress in the process of disintegration. Numerous strands of nuclear network are seen leading out from it bearing chromatin granules. The surface of the spiral itself has begun to show granule-bearing strands disposed over a groundwork which in some places appears to be homogeneous, in others shows traces of a fibrillar structure. In the neck of the archegonium, as shown in figure 16, a portion of the spermatozoid appears broken into short segments. I have seen many spermatozoids broken in this way. The segments formed in the various cases when compared suggest that they represent structural differences resulting in a characteristic mode of disintegration. The same character appears in figure 22 where the breaking of the segments has taken place after the entrance of the sperm-nucleus into the egg nucleus. I have not, however, succeeded in finding any structural basis for such segmentation.

Figures 19 and 20 show two sections of another egg in which fertilization has already taken place. Here again (fig. 19) we find the cytoplasmic envelope in the depression in the side of the nucleus. The extent of this depression may be seen by comparing the vertical diameter of the nucleus in figure 19 with the same diameter in figure 20. Although this cytoplasmic part is fainter and less distinct here than in figure 13, it can be followed easily and seems to be attached to the nuclear membrane of the egg at *a*. Only about a coil and a half of the sperm-nucleus can be seen here, but it still retains clearly its spiral character. Figures 23, 24 and 25 are successive sections of another egg. In figure 25 the cytoplasmic remnant can be seen in the cytoplasm outside the nucleus. In figure 24 two pieces of nuclear material are seen, one of which closely envelops a large nucleolus. The same occurs in figures 18 and 19, where the nucleolus *n* is inclosed by the turn formed by the union of *a*, figure 18, and *b*, figure 17. In figure 23 a large coil of the sperm-nucleus lies in the plane of the section. The disorganization of the spermatozoid has become quite marked here, especially in the portion *c* where it is reduced to a mass of granules showing few of the characters of the spiral nucleus as it enters.

As a matter of precaution against mistakes the eggs shown in figures 13, 17 and 18, and 23, 24 and 25, have been reconstructed in wax and gelatine. The spermatozoids have been carefully traced out their entire length and wire models of them have been made with the same magnification as the drawings, so that their course could be accurately determined (fig. 13).

If we take figure 26 as a still later stage in the fusion of the chromatin masses of the fertilized egg, we see that the changes are not the exact reverse of spermatogenesis. The destructive changes in the body of the spermatozoid are not so regular as the constructive changes. Instead of gradually swelling to show the strands, then short bars and finally the large distinct granules of chromatin so prominent in development, it now appears fringed on all sides with fine fibers or threads. These fibers bear very fine granules of chromatin like those of the egg nucleus, finer than the granules of the ordinary resting nucleus. Its surface appears broken or roughened by this process. These fibers are so abundant and so grouped and massed together in places as to form tangled masses like tufts of hair or cotton where the individual fiber is immediately lost to view. The entire surface is very soon involved in this disintegration process. In this we get further evidence that the nuclear portion of the spermatozoid is not truly homogeneous, if the study of its origin and cross-section are not sufficient. A large part of the mass appears fibrous. Probably these threads are the same material as the nuclear network — achromatin or linin. The chromatin granules as they separate from the mass can be seen along these threads. Sometimes the central mass shows the same tendency to stain red with safranin which was so noticeable in spermatogenesis. An identification of the fibrous material, which is linin or kinoplasm, with the red-staining central mass, which is probably fibrous also (and this as the derivative of the large nucleoli of the spermatid), while not demonstrable in the material studied, offers the most satisfactory explanation of the successive appearances of these substances. In the spermatid the two or more large nucleoli disappear when spermatogenesis begins and a red-staining "ground substance" appears which can be traced in the adult spermatozoid. Inside the egg nucleus we see the red substance at times, but always see the fibrous material which seems to come directly from the central mass of the spermatozoid. While the evidence is not conclusive, the presence of a comparatively large amount of kinoplasmic material in the ordinary nucleus is good ground for expecting to find it here in some form. The active movement of the nuclear portion while the ripe spermatozoid swims through the water would call for the presence of such material. Its ability to move itself while entering the egg nucleus without the assistance of cilia or cytoplasmic materials points toward the same conclusion. Further, as noticed before, if we compare the chromatin matter as found in the egg in such figures as we have here, with the whole mass of the spermatozoid nucleus regarded as "homogeneous chromatin," the spermatozoid would carry in with it a great preponderance of chromatin. There certainly is no such extrusion of non-chromatin in material from the sperm-nucleus as Ikeno has figured for *Cycas revoluta.* Whether Ikeno is correct or not, in claiming that only chromatin is essential in fertilization, we certainly have here much other material carried into the egg-nucleus. The entire nuclear portion of the spermatozoid enters bodily into the nucleus of the egg without (here my observations agree with Ikeno for *Cycas*) increasing the size of the egg nucleus to any appreciable extent. The resulting segmentation nucleus shows no increase in size, but does present a doubling of the quantity of its chromatin. Only that portion of the spermatozoid which comes to lie inside of the nucleus of the egg is known to have any function in fertilization, in forms which like the ferns have *no centrosome.* Whatever its value may be, the cytoplasmic portion of the spermatozoid is absorbed in the cytoplasm of the egg and its effects cannot be traced.

The segmentation nucleus gradually loses its irregular contour and begins to assume an elliptical outline (fig. 26). The depressions in the surface of the cell and nucleus disappear. The cytoplasm usually shows a more markedly radiate arrangement outward from the nucleus. In the same figure (fig. 26) I find in the cytoplasm fibers running from the nuclear membrane toward the periphery of the cell which correspond in course and staining capacity with the fibers of the spindle. This figure may then be regarded as representing the earliest indications of the first division spindle in the embryo and the process of fertilization must be regarded as completed.

Although in the course of this investigation I have sectioned many embryos, I have not yet attempted to carry my investigation further into the details of the formation of the embryo itself.

The observations above and a consideration of my figures give convincing evidence that the course of fertilization in *Aspidium* and *Adiantum* at least, and probably in many other ferns, differs greatly from the generally accepted description. The entrance of an unchanged sperm-nucleus into the egg nucleus has been described already by Shaw for *Onoclea* and Ikeno for *Cycas*. Shaw has found the spermatozoid entering the egg-cytoplasm. He has figured the sperm-nucleus within the egg-nucleus. I have been able to show the unchanged spermatozoid as it lies coiled in the depression in the surface of the cell and to trace it into the cytoplasm of the egg, through the nuclear membrane, to the actual mixing of the chromatin of spermatozoid and egg. I have shown that the entire sperm-nucleus slips out of the cytoplasmic envelope, or mantle (to use Ikeno's term), just as it reaches the nuclear membrane of the egg, so that it passes directly from its own cytoplasmic sheath into the egg nucleus. In *Cycas* it appears to leave its cytoplasm near the periphery of the egg. The nucleus of the spermatozoid carries in with it other material besides chromatin. This material forms the central mass, and is surrounded by the chromatin. Such a conclusion agrees with the ordinarily accepted views of fertilization more closely than with the conclusions of Ikeno. The whole nuclear portion of the spermatozoid here enters the nucleus directly. In the fertilization figures for animals such as *Nereis* (Wilson, p. 141) we find that the sperm-nucleus has swollen and assumed all the characters of an ordinary nucleus, so that the gametes are equal, not only qualitatively but quantitatively, at the time of fusion. In the phanerogams, as far as described, we never find these changes in structure in the generative nucleus of the pollen-tube which are characteristic of spermatogenesis. Fusion is there a union of entire nuclei. The generative nucleus is carried in the end of the pollen-tube until in contact with the egg or nearly so. Similarly in the fern the entire nucleus is carried in its cytoplasmic envelope until it is actually within the cytoplasm of the egg cell.

SUMMARY OF RESULTS.

1. As the spermatozoid enters the mouth of the archegonium it consists of a proximal (with reference to the egg) cytoplasmic portion of about one and a half coils and a distal nuclear portion of about two spiral coils.

2. The cytoplasmic forward end contains or is partially derived from the so-called "blepharoplast" and bears numerous long cilia. This part either becomes disconnected entirely before the spermatozoid reaches the egg, or, becoming functionless, is turned backward and dragged passively along into the cytoplasm of the egg.

3. The sperm-nucleus consists of an outer homogeneous appearing chromatin mass and an inner "ground substance" derived apparently from the nucleoli of the spermatid. The whole body is surrounded by a cytoplasmic envelope.

4. The nucleus once inside the archegonium displays the power of motion toward and into the egg independently of its ciliate anterior end, which indicates that the attractive impulse which leads to fertilization is exerted directly between the nuclei.

5. The egg has a concave depression in its outer surface in which the spermatozoid is found coiled before fertilization.

6. The egg nucleus has an irregular branching form extending through the cytoplasm in all directions. It contains one or more prominent nucleoli and a network bearing extremely minute chromatin granules. It has on its outer surface a concavity similar to and nearly parallel with the concavity in the surface of the cell, and approaches most nearly to the surface at this point.

7. The nuclear coils of the spermatozoid lying in the concavity of the egg break their way into the cytoplasm of the

egg toward the nucleus at the point where it lies nearest the surface. The nucleus itself is still inclosed in the cytoplasmic envelope. When it reaches the nuclear membrane it finds or breaks an opening into the egg nucleus, and, escaping from its cytoplasmic covering, passes unchanged into the nucleus of the egg. The cytoplasmic envelope is left in the egg cytoplasm where it disappears.

8. The entrance of the sperm nucleus here, as in *Cycas*, does not increase the size of the egg nucleus.

9. After entering the egg nucleus the sperm nucleus begins at once to assume the "resting stage" by breaking up into the nuclear network or reticulum bearing fine chromatin granules. This network is from the first so fused or entangled with the network of the egg nucleus already present that it is impossible to distinguish any difference between the sexual elements in the fertilized egg after the form of the spermatozoid disappears.

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EXPLANATION OF ILLUSTRATIONS.

PLATES XXXVI.–XXXVIII.

Figures 1 to 41, except figures 6 and 26, are magnified 850 diameters. Figures 6 and 26 are magnified 1100 diameters, and figure 42 is magnified 2550 diameters. Figures 43 to 49 are diagrams drawn with a camera.

1, Vertical longitudinal section of archegonium showing egg-cell and spermatozoids coiled upon it. Other spermatozoids are seen entering the neck of the archegonium. — 2–3, Successive sections of an archegonium. The spermatozoids *a* and *b* are seen entering blunt end first. In Fig. 3 a spermatozoid is seen in the depression in the surface of the egg-cell. — 4–5, Sections of another archegonium. The spermatozoid *f* is seen entering the egg-cytoplasm; *s* is a spermatozoid in the neck of the archegonium. *c* is the cytoplasmic anterior end. *c'* same for *f* turned backward.— 4a, A spermatozoid which lay in the mouth of an archegonium, *c* its cytoplasmic anterior end already disconnected. — 6–8, Successive sections of an egg; *s*, spermatozoid entering. — 9, Vertical longitudinal section of archegonium with a spermatozoid lying in the neck and another entering the egg. — 10, Fertilization of the egg. *v*, Depression in surface of egg appearing as a hole in section with the spermatozoid *f* partially coiled in it. — 11, Fertilization of the egg; spermatozoid entering as before. — 12, Fertilization of the egg; spermatozoid entering the egg at its tip. — 13–13a, Entrance of sperm-nucleus into egg-nucleus. *a–b* cytoplasmic envelope of nucleus lying outside egg-nucleus and extending into it at *b*. Fig. 13a is a diagram of Fig. 13, turned 90 degrees on the axis *x–y*. — 14–16, Fertilized egg in successive sections. *d*, a conical depression in surface of nucleus; *c*, cytoplasmic anterior end left outside the egg-nucleus. — 17, 18, and 18a, two successive sections of a fertilized egg and a diagram of the same egg viewed from above; *c*, *c'* the cytoplasmic envelope of the sperm nucleus left outside the egg nucleus. — 19–20, Two sections of another fertilized egg, showing the cytoplasmic sheath outside the nucleus in Fig. 19 and the sperm-nucleus inside the egg-nucleus in Fig. 20. — 21–22, Fertilized eggs showing unchanged sperm-nuclei.— 23–25, Successive sections of a fertilized egg.— 26, Fertilized egg where the disorganization of the sperm-nucleus has gone much farther.— 27–41, Stages in the development of the spermatozoid. — 42, Cross-section of ripe spermatozoid. — 43, Diagram of archegonium in vertical longitudinal section. — 44-48, Diagrams of the egg-cell. — 49, Cross-section of prothallium showing two embryos in the same calyptra; *c*, cotyledon; *F*, foot; *r*, root; *s*, stem.

Issued August 4, 1899.

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Issued January 24, 1900.

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